



RAJANIKANTH M
(IIT KANPUR)

RAY OPTICS

RAJANIKANTH (RK'SIR IIT KANPUR)

**A NEW APPROACH TO NCERT:
CONCEPT CLARITY + ESSAY-
STYLE LEARNING**

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Mallisetty Rajinikanth, the founder of Mind Waves Edtech, is a brilliant educator and innovator. He has developed a revolutionary platform that uses Blockchain technology from IIT Kanpur to provide online books, classes, and tuition to students worldwide.

Rajinikanth's vision is to make quality education accessible to everyone, everywhere. With Mind Waves Edtech, students can learn from the best teachers and resources, no matter where they are in the world.

What's impressive is that Rajinikanth has leveraged the power of Blockchain technology to create a secure, transparent, and efficient learning platform. This ensures that students receive authentic and reliable educational content, and that their progress is tracked and verified.

Mind Waves Edtech is a game-changer in the world of education, and Rajinikanth's leadership and expertise are at the forefront of this innovation. He is making a positive impact on the lives of students globally, and his work will undoubtedly shape the future of education."

20/03/2024 :
(Wednesday)

L:① * RAY OPTICS *

- > Light is a form of energy. It belongs to electromagnetic spectrum.
- > In electromagnetic spectrum visible region is called Light.
- > The wavelength of the light is $4000 \text{ \AA}$ to $7000 \text{ \AA}$.
- > In vacuum, all colours consists same Speed.
- > This speed of light
$$c = 2.99794 \times 10^8 \text{ m/s (or)}$$
$$c = 3 \times 10^8 \text{ m/s}$$
- > In electromagnetic spectrum, red colour has max. wavelength and min. energy.
- > The violet colour has min. wavelength and max. energy.

Formula:-

$$\text{Energy of each photon (E)} = \frac{hc}{\lambda}$$

- **
→ When light ray travel from, rarer medium to denser medium a part of light bounce back it is called Reflected ray.
- Remaining part of light passes through the another medium it is called Refracted ray.
- The reflected ray consists same speed, same wavelength, same frequency but intensity decreases.
- When light ray travel from rarer medium to denser medium (Air to glass). The phase difference is π radian (or) 180° .
- When light ray travel from one medium to another medium wavelength decreases, Speed decreases but frequency remains constant.

$$\frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

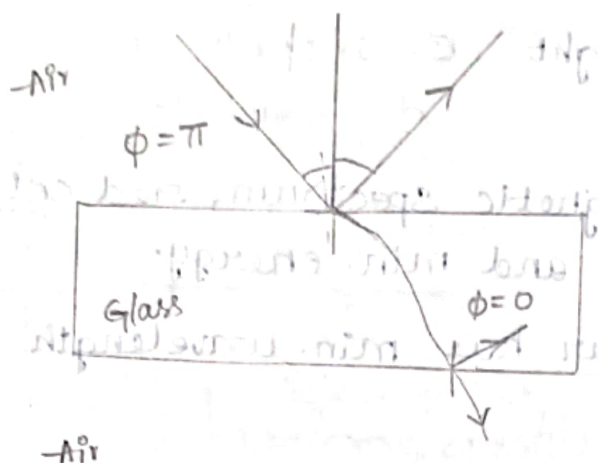
$$v_1 = v\lambda_1 \rightarrow (1)$$

$$v_2 = v\lambda_2 \rightarrow (2)$$

$$\frac{(1)}{(2)} \Rightarrow \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

Adv

When light ray travel from denser medium to rarer medium (Glass to air) the phase difference b/w incident ray and reflected ray is 0° (or) 2π

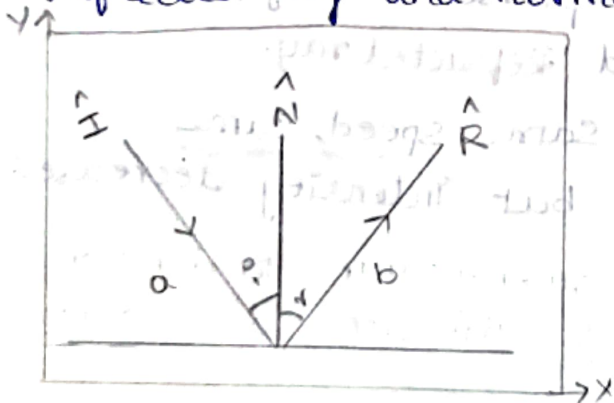


* LAW OF REFLECTION:-

- According to law of reflection, the angle of incidence is numerically equal to angle of reflection.

$$\angle i = \angle r$$

- According to law of reflection, incident ray, reflected ray and normal, all are in same plane.

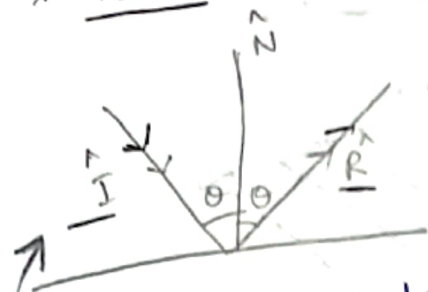


$$\begin{aligned}\hat{I} \cdot (\hat{N} \times \hat{R}) &= 0 \\ \hat{R} \cdot (\hat{I} \times \hat{N}) &= 0 \\ \hat{N} \cdot (\hat{I} \times \hat{R}) &= 0\end{aligned}$$

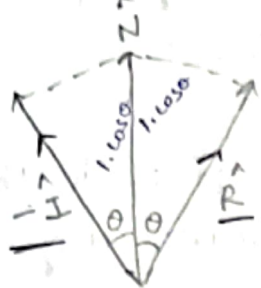
$$\vec{P} \cdot \vec{\phi} = PQ \cos \theta$$

$$\begin{aligned}\hat{I} \cdot (\hat{N} \times \hat{R}) &= PQ \cos 90^\circ \\ &= PQ(0) = 0\end{aligned}$$

* Vector form of reflected ray :- 21/03/2024 (Thu)



According to ; law of vector addition.



$$|\hat{R} - \hat{I}| = |\hat{R} + (-\hat{I})|$$

$$|\hat{R} - \hat{I}| = 1 \cdot \cos \theta + 1 \cdot \cos \theta \rightarrow [1 \Rightarrow \text{magnitude of } \hat{R} \text{ and } \hat{I}]$$

$$(\hat{R} - \hat{I}) = 2 \cos \theta \hat{N}$$

$$\hat{R} = \hat{I} + 2 \cos \theta \hat{N}$$

(1 $\Rightarrow$ magnitude of $\hat{I}$ & $\hat{N}$ unit vectors)

$$\hat{I} \cdot \hat{N} = 1 \cdot 1 \cdot \cos(180^\circ - \theta)$$

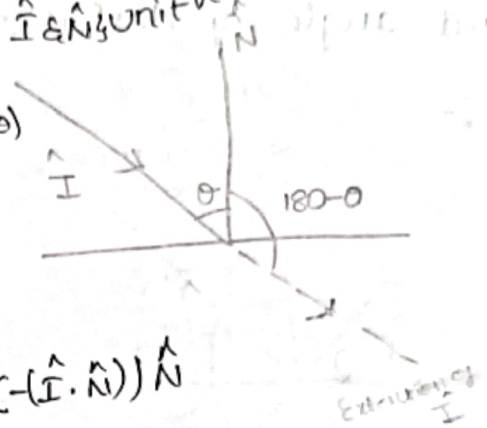
$$\hat{I} \cdot \hat{N} = -\cos \theta$$

$$\hat{R} = \hat{I} - 2(\hat{I} \cdot \hat{N}) \hat{N}$$

Jee-Mains (From I)

$$\hat{R} = \hat{I} + 2(-\hat{I} \cdot \hat{N}) \hat{N}$$

$$\hat{R} = \hat{I} - 2(\hat{I} \cdot \hat{N}) \hat{N}$$

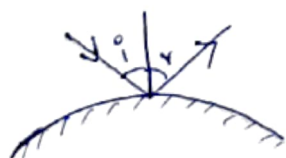


Let the incident ray is $\hat{I}$. The reflected ray is $\hat{R}$. The normal is $\hat{N}$. As show in the above figure.

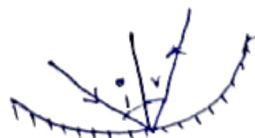
22/03/2024 (Fri):

* Law of Reflection Obeys for all reflecting Surfaces :-

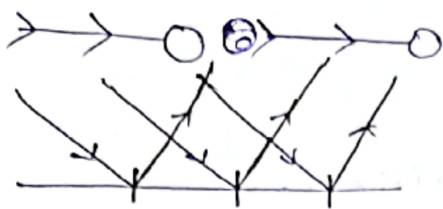
① Convex :-



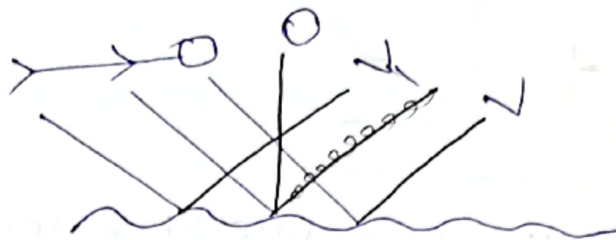
② concave :-



③ Plane Surface :-



④ Rough surface :-

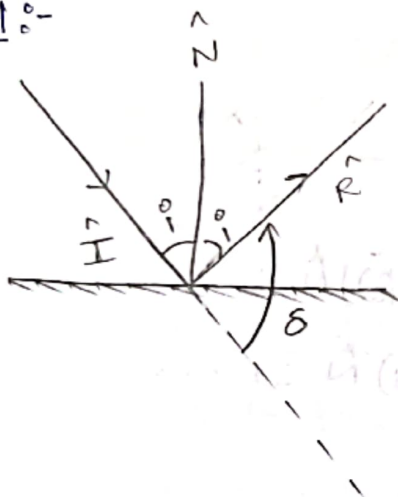


Diffusion of light

* Angle of Deviation for one Reflection :-

Q) Let a light ray incident at an angle i with the normal it makes reflection with the same angle. Find angle of deviation?

Sol :-



$$180^\circ = i + i + \delta$$

$$\delta = 180^\circ - 2i$$

or

$$\delta = \pi - 2i$$

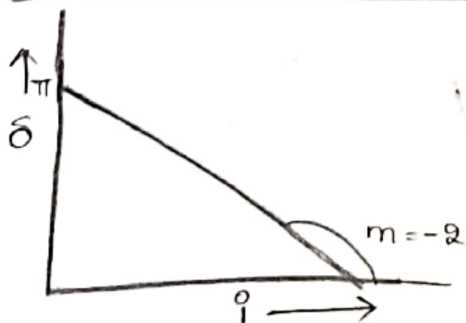
→ (I)

Graph :-

A graph drawn between angle of deviation on Y-axis & angle of incidence on X-axis the nature of the graph is

$$Y = mx + C$$

$$\delta = -2i + \pi \quad (\text{From I})$$



Case-① :-

If $i = 0$ then $\delta_{\max} = \pi$

$$0 + \pi = \pi$$

$$\delta_{\max} = \pi$$

Case-② :-

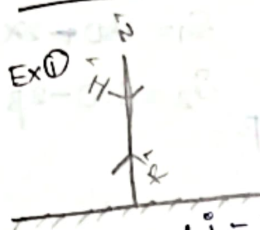
If $i = \pi/2$ then $\delta_{\min} = 0$

$$\delta = -2 \times \frac{\pi}{2} + \pi$$

$$\delta = -\pi + \pi = 0$$

$$\delta_{\min} = 0$$

Case-① :-



$$L_i = L_r = 0$$

$$\delta_{\max} = \pi$$

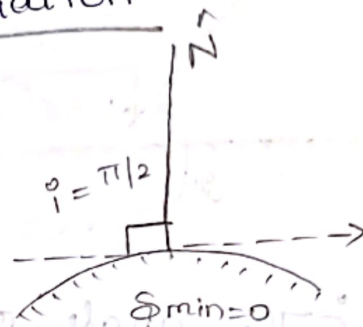
Ex ①

When light ray incident normal to the surface (or) parallel to the normal line after reflection it is parallel to the normal.

→ It has max. deviation.

Case-② :-

Ex: When light ray perpendicular to the normal it has min. angle of deviation.



(Q) Let a light ray incident at an angle 30° with the normal. The angle of deviation is ? (Jee)

WKT,

$$\delta = \pi - 2i \quad \text{or} \quad \delta = 180^\circ - 2i$$

But, $i = 30^\circ$ (given)

$$\delta = 180^\circ - 2(30^\circ)$$

$$\delta = 180^\circ - 60^\circ$$

$$\delta = 120^\circ$$

$\delta = 120^\circ$ (Anti-clockwise)

* Note:- Angle of deviation in anticlockwise taken as positive (+ve).

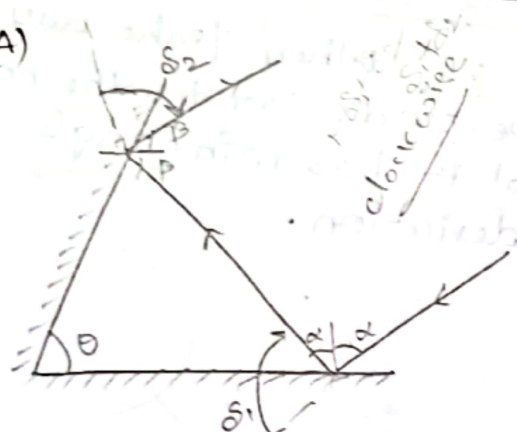
→ In angle of deviation clockwise taken as negative (-ve).

~~Q(1)~~

* > (Q)

Two reflecting surfaces makes the angle θ with the each other. Find total angle of deviation?

(A)



$$\delta_{net} = \delta_1 + \delta_2$$

$$\delta_1 = 180 - 2\alpha$$

$$\delta_2 = 180 - 2\beta$$

$$= 180 - 2\alpha + 180 - 2\beta$$

$$= 360 - 2(\alpha + \beta)$$

Sum of exterior angles = interior angles.

$$\delta_{net} = 360 - 2\theta$$

* Note:- The angle of deviation depends on angle b/w two reflecting surfaces. It does not depend on angle of incidence.

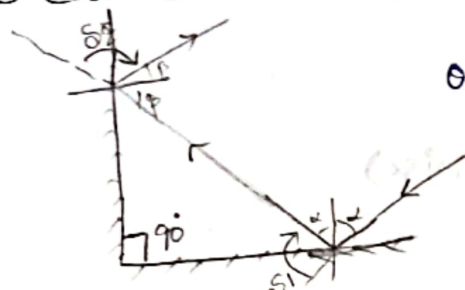
(α, β)

23/03/2024 (Sat):-

> (Q) Two perpendicular reflecting surfaces incident ray parallel to the second reflecting surface

(Jee-2024) Jan.

X(Q) Two reflecting mirrors arranged per to each other the incident ray and reflected ray parallel to each other the total angle of deviation?



$$\theta = \alpha + \beta = 90^\circ$$

$$\delta_{net} = 360 - 2\theta$$

$$= 360 - 2(90^\circ)$$

$$\delta_{net} = 360 - 180^\circ \Rightarrow \boxed{\delta_{net} = 180^\circ}$$

$$\delta_1 = 180^\circ - 2\alpha$$

$$\delta_2 = 180^\circ - 2\beta$$

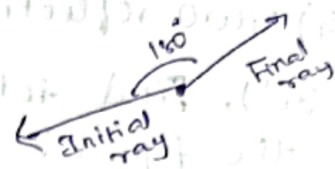
$$\delta_{net} = \delta_1 + \delta_2$$

$$= 180^\circ - 2\alpha + 180^\circ - 2\beta$$

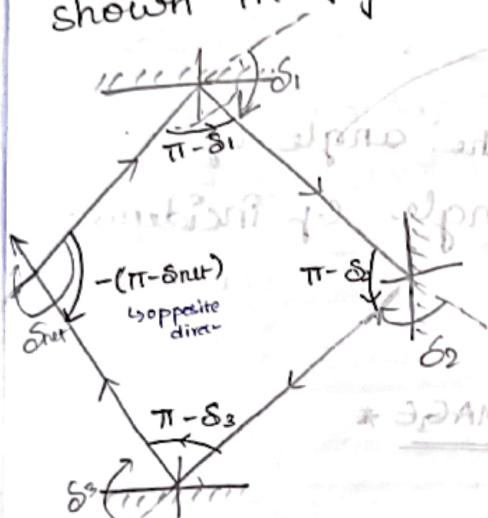
$$= 360^\circ - 2(\alpha + \beta)$$

$$= 360^\circ - 2(90^\circ) = 360^\circ - 180^\circ = 180^\circ$$

$$\boxed{\delta_{net} = 180^\circ}$$



> (Q) Three reflecting surfaces arranged as shown in figure. Find total angular deviation?



$$2\pi = \pi - \delta_1 + \pi - \delta_2 + \pi - \delta_3 - (\pi - \delta_{net})$$

$$2\pi = 2\pi - \delta_1 - \delta_2 - \delta_3 + \delta_{net}$$

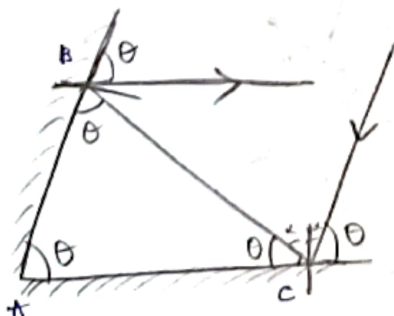
$$0 = -\delta_1 - \delta_2 - \delta_3 + \delta_{net}$$

$$\boxed{\delta_{net} = \delta_1 + \delta_2 + \delta_3}$$

★★

★

> (Q) Two reflecting plane surfaces makes an angle θ . The incident ray parallel to the second mirror and after two reflections parallel to the first mirror the angle b/w the plane mirrors.

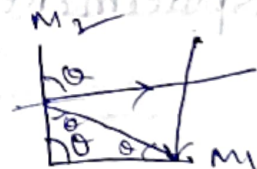


From $\triangle ABC$

$$180^\circ = \theta + \theta + \theta$$

$$180^\circ = 3\theta$$

$$\boxed{\theta = 60^\circ}$$

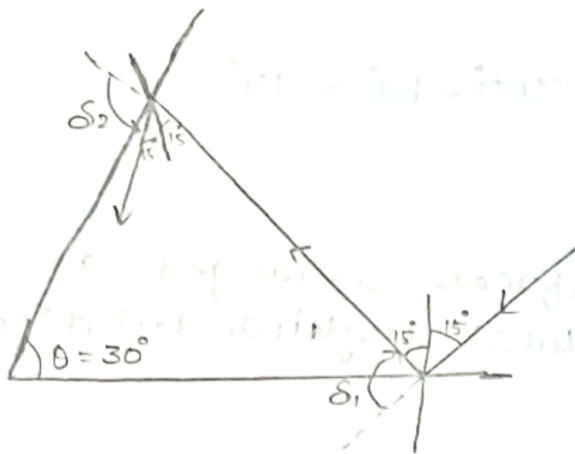


$$3\theta = 180^\circ$$

$$\boxed{\theta = 60^\circ}$$

> (Q) Two reflecting surfaces makes an angle θ ($\theta = 30^\circ$). Find total angle of deviation as shown in the figure.

(A)



$$\delta = 360^\circ - 2\theta$$

$$\delta = 360^\circ - 2(30^\circ)$$

$$\delta = 360^\circ - 60^\circ$$

$$\boxed{\delta = 300^\circ}$$

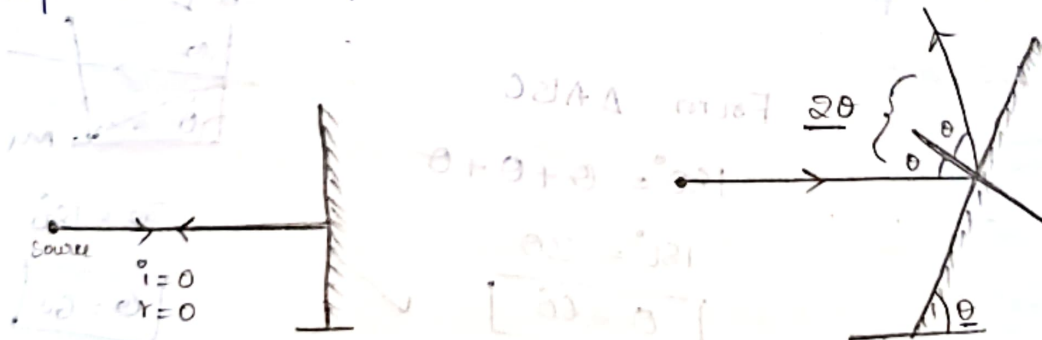
* Note:- For two reflecting surfaces, the angle of deviation doesn't depend on angle of incidence.

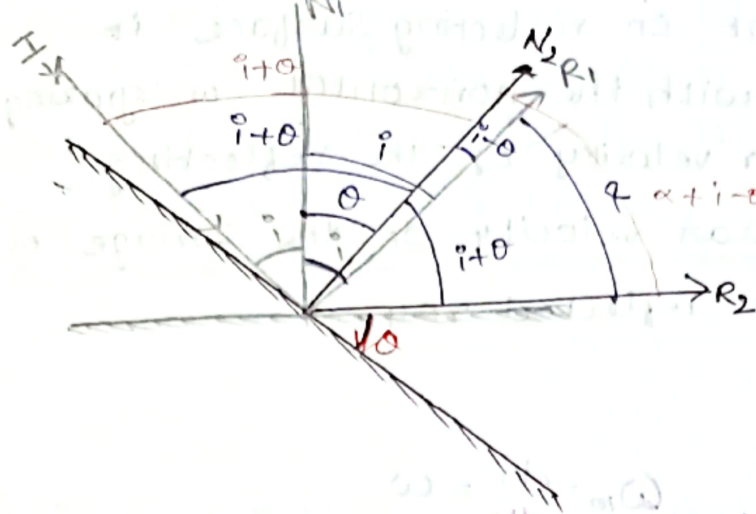
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* ROTATION OF IMAGE *

Introduction:-

Let a light ray is incident at an angle i with the normal. After the reflection, it makes same angle. If reflecting surface rotate at an angle θ the angular displacement of the image or angular displacement of the reflected ray.





$$i + \theta = r - \theta + \alpha$$

$$\alpha = 2\theta$$

Note: If plane mirror rotate at angle θ in clockwise the reflected ray rotate 2θ in clockwise.

$$\theta_m = \theta$$

$$\theta_r = 2\theta$$

The angular velocity of the rotating mirror is ω . Find angular velocity of reflected ray?

$$\omega_m = \frac{d\theta}{dt}$$

$$\omega_r = 2 \cdot \frac{d\theta}{dt}$$

$$\omega_r = 2 \cdot \omega_m$$

26/03/2024 (Tue):-

Adv level :-

> (Q) A straight light ray makes an angle θ with the initial direction the angle of deviation as shown in figure



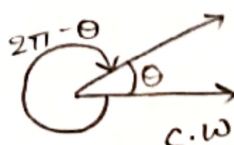
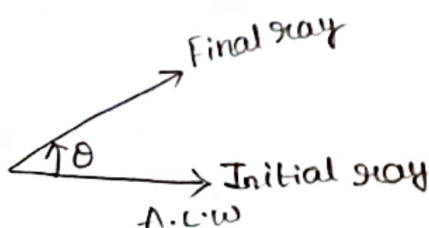
$$\textcircled{1} \delta = \theta \text{ (A.C.W)}$$

$$\textcircled{2} \delta = 2\pi - \theta \text{ (C.W)}$$

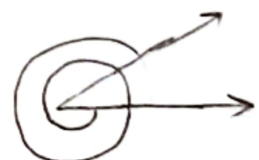
$$\textcircled{3} \delta = 2n\pi - \theta \text{ (C.W)}$$

$$\textcircled{4} \delta = 2n\pi + \theta \text{ (A.C.W)}$$

Sol:-



$$\delta = 2n\pi + \theta$$



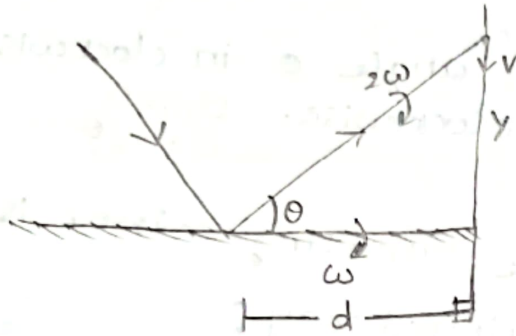
$$\delta = 2\pi + 2\pi - \theta$$

$$\delta = 4\pi - \theta$$

$$\delta = 2n\pi - \theta$$

> (Q) A light ray incident on reflecting surface it makes an angle θ with the horizontal or grazing angle θ . The angular velocity of the reflecting surface (ω). The linear velocity of the Image or linear velocity of the reflected ray.

11T-Adv.



$$\omega_m = \frac{d\theta}{dt} = \omega$$

$$\omega_r = \omega_{\text{Image}} = 2\omega$$

$$\tan \theta = \frac{y}{d} \Rightarrow y = d \tan \theta$$

$$\frac{dy}{dt} = d \tan \theta$$

$$\frac{dy}{dt} = d \sec^2 \theta \left(\frac{d\theta}{dt} \right)$$

$$\frac{dy}{dt} = d \sec^2 \theta (\omega_{\text{Image}})$$

$$V = d \sec^2 \theta 2\omega$$

$$\boxed{V = 2\omega d \sec^2 \theta} \checkmark$$

Method-2 :

$$d = R \cos \theta$$

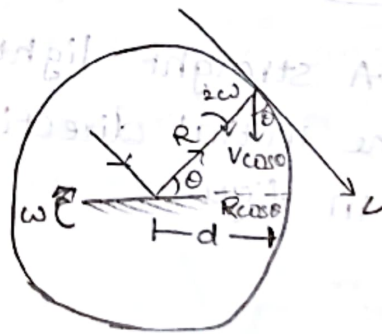
$$R = \frac{d}{\cos \theta}$$

$$\boxed{R = d \sec \theta}$$

$$V \cos \theta = R (2\omega)$$

$$V \cos \theta = d \sec \theta (2\omega)$$

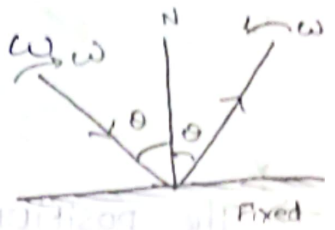
$$\boxed{V = 2\omega d \sec^2 \theta}$$



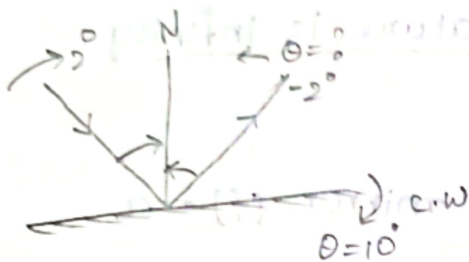
> (Q) A reflecting surface is fixed and light ray rotates with constant angular velocity ω . The angular velocity of the reflected ray is

Angular velocity of incident ray $\overline{\omega}_i = \omega$

Angular velocity of reflected ray $\overline{\omega}_r = -2\omega$



> (Q) A reflecting surface makes an angle 10° in clock-wise and incident ray rotates an angle 2° in clock-wise. Find rotating angle of the image.



$$\theta_m = 10^\circ$$

$$\theta_i = 2\theta_m = 2 \times 10^\circ = 20^\circ$$

$$\theta_r = 20^\circ - 2^\circ = 18^\circ$$

26/03/2024 :

(Tue) :

* MIRRORS * ②

> Mirrors :- Mirrors are classified into three types

(i) plane mirror

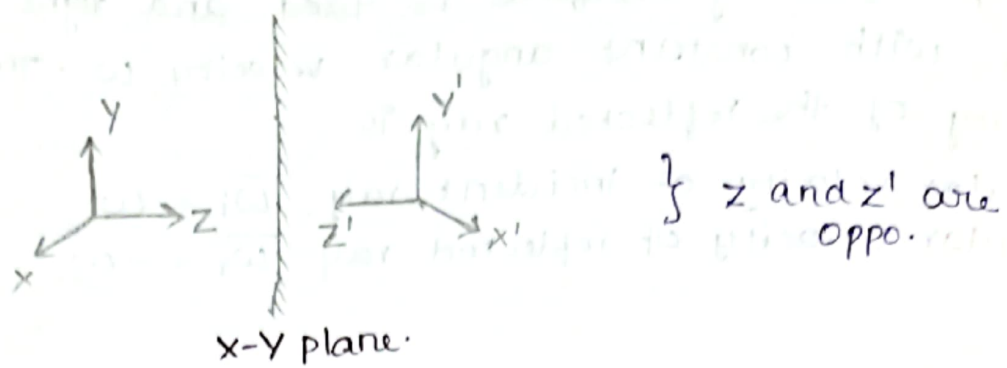
(ii) Convex mirror

(iii) concave mirror

> Plane Mirrors :-

→ Introduction : A plane transparent glass sheet coated with silver and covered with paint. The silver has highest reflecting metal in nature. Such arrangement is called mirror.

→ In plane mirror, object act as a right-hand coordinates, image act as a left-hand coordinates



→* The position of the object $O = x\hat{i} + y\hat{j} + z\hat{k}$ ✓

The position of the image $I = x\hat{i} + y\hat{j} - z\hat{k}$ ✓

→ In plane mirror object distance & image distance are same.

→* In plane mirror radius of curvature is infinity
($R = \infty$) ✓

→* The focal length of the plane mirror (f) = ∞

Focal length $\propto$ Radius

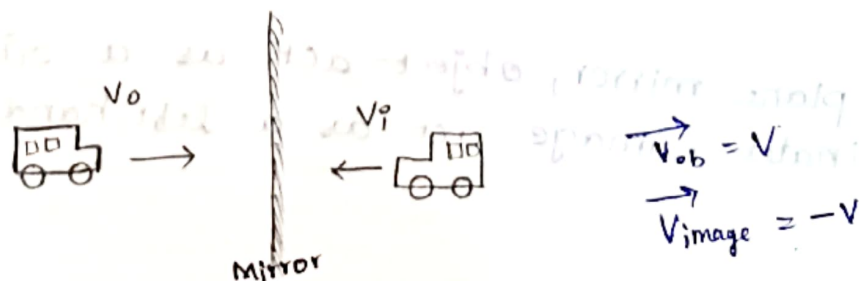
→* power of plane mirror (P) = $\frac{1}{f}$
 $(P) = \frac{1}{\infty} = 0$.

Focal length $\propto \frac{1}{\text{power}}$

* Power:- The ability of the mirror or lens to bend the light rays is power.

27/03/2024 :- (Wed) :-

→ In plane mirror, Speed of object is equal to Speed of image but in opposite direction.



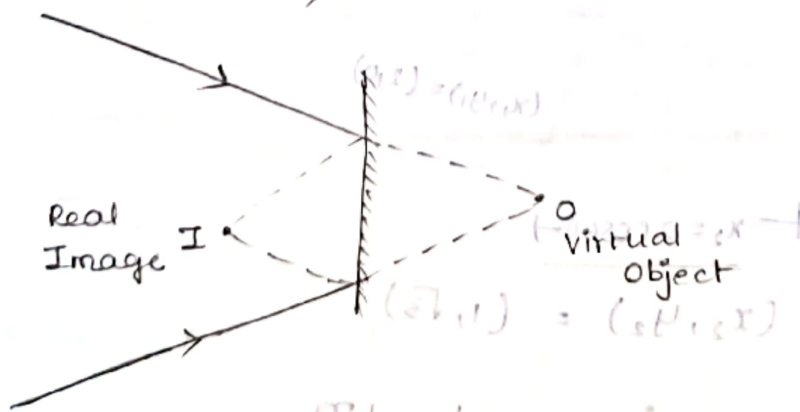
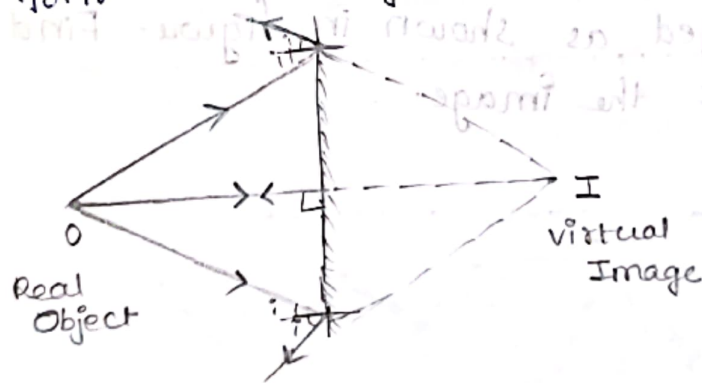
* Magnification (or) Lateral magnification :-

> The ratio of height of the image to height of the object is called Magnification (or) Lateral magnification.



* Note :- In plane mirror, object distance and image distance always shortest distance and normal to the mirror.

> When object at infinite distance from the plane mirror (or) point object arrange near the plane mirror it form the image as show in figure.

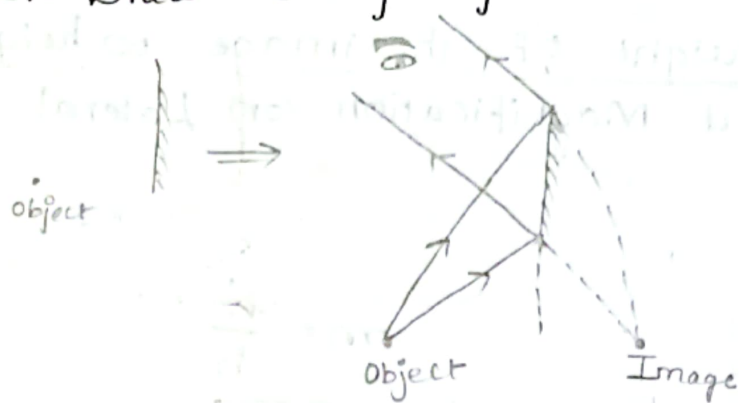


$$m = \frac{1}{\infty} \times \infty = 1$$

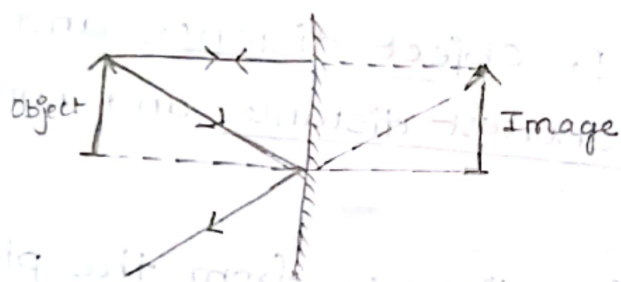
$$m = \frac{\infty}{\infty} = 1$$

$$m = \frac{h'}{h} = \frac{\infty}{\infty} = 1$$

> (Q) Draw the ray diagram as show in figure.



> (Q) Draw a ray diagram for extended objects as shown in figure.



See-Mainly

> (Q) A plane mirror, makes an angle 30° with the X-axis arranged as shown in figure. Find the coordinates of the image.

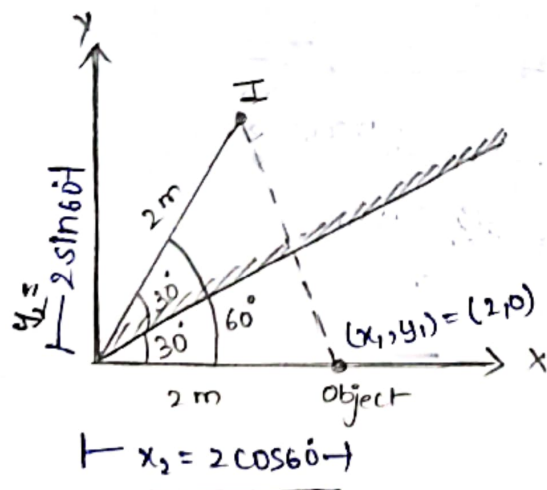


Image $(x_2, y_2) = (1, \sqrt{3})$

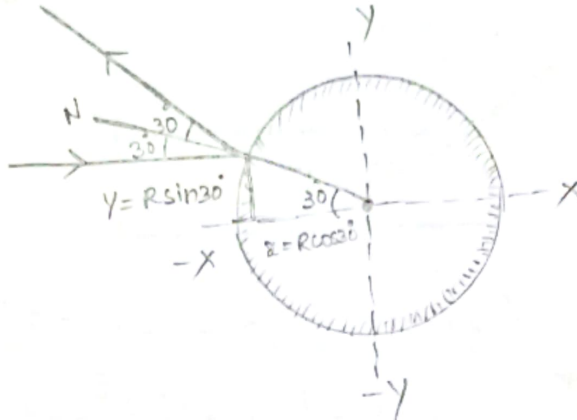
$$x_2 = 2 \cos 60^\circ = 2 \times \frac{1}{2} = 1 \text{ m}$$

$$y_2 = 2 \sin 60^\circ = 2 \times \frac{\sqrt{3}}{2} = \sqrt{3} \text{ m}$$

$$\boxed{(x_2, y_2) = (1, \sqrt{3})} \checkmark$$

> (Q) A light ray makes angle of deviation 120° when it is incident on Spherical mirror. Find coordinates of the Spherical mirror about the Centre.

See-Adv:-



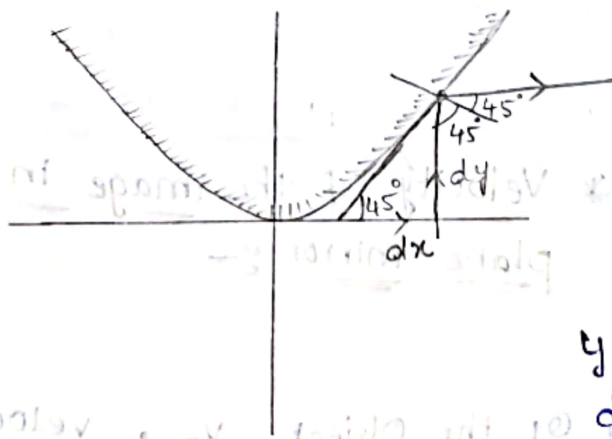
$$(x, y) = \left(-\frac{\sqrt{3}}{2} R, \frac{R}{2} \right)$$

On x-axis $\Rightarrow x = R \cos 30^\circ$

$$x = \frac{\sqrt{3}}{2} R$$

On y-axis $\Rightarrow y = R \sin 30^\circ \Rightarrow y = \frac{R}{2}$

> (Q) The reflecting surface represents eqn $y = 4x^2$. A light ray becomes normal to the initial path after reflection as shown in figure. The coordinate is:-



$$\tan \theta = \frac{dy}{dx}$$

$$\tan 45^\circ = 1$$

$$\frac{dy}{dx} = 1$$

$$y = 4x^2$$

$$\frac{dy}{dx} = 8x$$

$$y = 4x^2$$

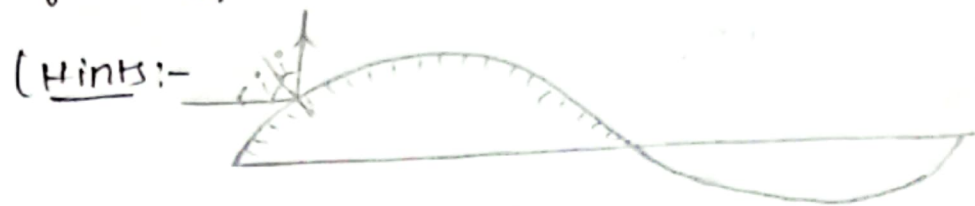
$$y = \frac{1}{16}$$

$$x = \frac{1}{8}$$

$$(x, y) = \left(\frac{1}{8}, \frac{1}{16} \right)$$

H.W :-

The reflecting surface represents eqn $y = \frac{2L}{\pi} \sin\left(\frac{\pi x}{L}\right)$.
 The incident ray becomes normal to the initial path after reflection. Find coordinates of the given point.



$$y = \frac{2L}{\pi} \sin\left(\frac{\pi x}{L}\right)$$

$$\frac{dy}{dx} = \frac{2L}{\pi} \cos\left(\frac{\pi x}{L}\right) \times \frac{\pi}{L}$$

$$y = \frac{2L}{\pi} \sin\left(\frac{\pi x}{L}\right)$$

$$\tan \theta = \frac{dy}{dx}$$

$$1 = 2 \cos\left(\frac{\pi x}{L}\right)$$

$$y = \frac{2L}{\pi} \sin\left(\frac{\pi}{3}\right)$$

$$\tan \theta = 1$$

$$1 = \frac{dy}{dx}$$

$$\cos\left(\frac{\pi x}{L}\right) = \frac{1}{2}$$

$$\frac{\pi x}{L} = \cos^{-1}\left(\frac{1}{2}\right)$$

$$y = \frac{\sqrt{3}L}{\pi}$$

$$\frac{\pi x}{L} = \frac{\pi}{3}$$

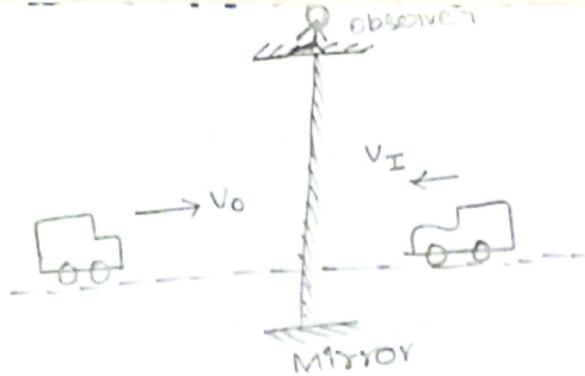
$$x = \frac{L}{3}$$

28/03/2024 :-

(Thru):-

* Velocity of the image in plane mirror :-

> Let velocity of the object v_o , velocity of the image v_I and velocity of the mirror v_M arranged as show in figure.



$$V_{OM} = -V_{IM} \quad \checkmark$$

$$V_o - V_M = -(V_I - V_M)$$

$$V_o - V_M = -V_I + V_M$$

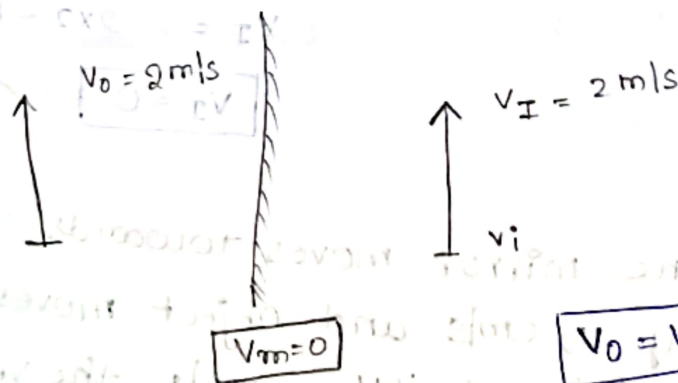
$$V_o + V_I = V_M + V_M$$

$$\star V_I = 2V_M - V_o \quad \star \checkmark \quad (A)$$

* Note :- Above formula, is applicable for perpendicular components for the plane mirror. It is not applicable for parallel components to the plane mirror.

⇒ CASE - I :-

When object moves parallel to the mirror image & object consists same velocity



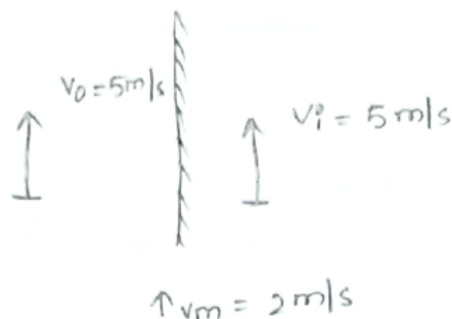
$$V_o = V_I \quad \checkmark$$

$$\begin{aligned} V_I &= 2V_M - V_o \\ &= 2(0) - V_o \\ V_I &= -V_o \\ &= -(-2) \\ &= 2 \end{aligned}$$

⇒ CASE - II :-

When object and plane mirror moves parallel to each other the velocity of the image is

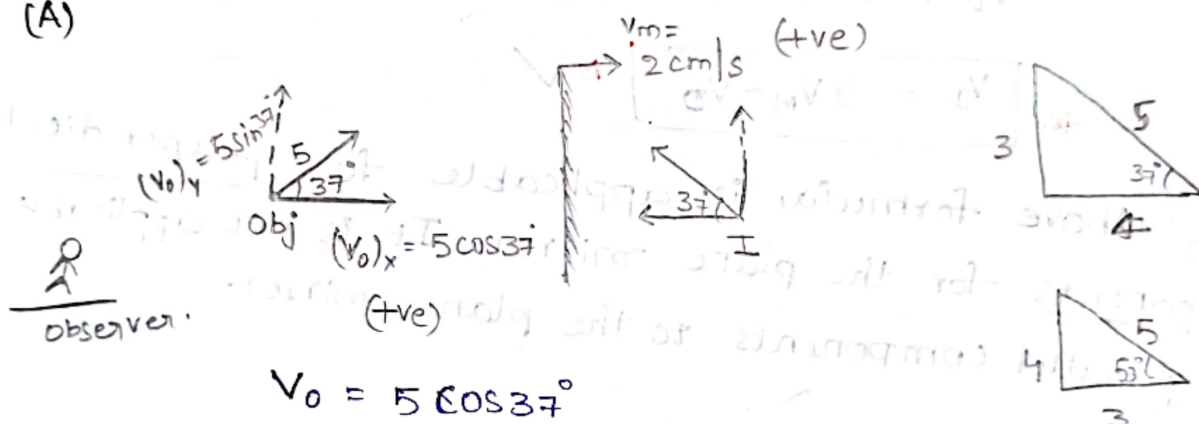
$$V_o = V_i = 5 \text{ m/s}$$



Mains:

> (Q) A plane mirror moves away from the object with velocity 2 m/s . The object makes an angle 37° with the horizontal and moves with the velocity 5 cm/s . Find velocity of the image?

(A)



$$V_o = 5 \cos 37^\circ$$

$$V_o = 5 \times \frac{4}{5} = 4 \text{ cm/s}$$

$$V_m = 2 \text{ cm/s}$$

Velocity of the image

$$V_I = 2V_m - V_o$$

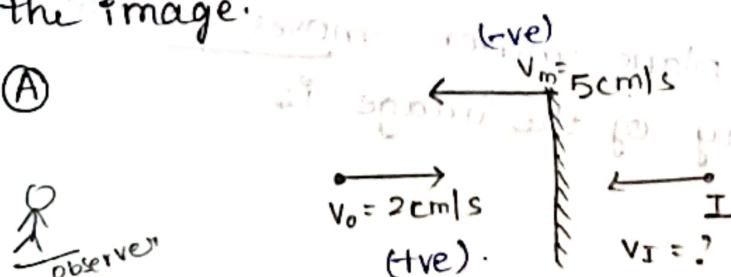
$$V_I = 2 \times 2 - 4$$

$$V_I = 0$$

Mains:

> (Q) A plane mirror moves towards the observer with velocity 5 cm/s and object moves towards the mirror with velocity 2 cm/s the velocity of the image.

(A)



velocity of the Image $V_I = 2V_m - V_o$

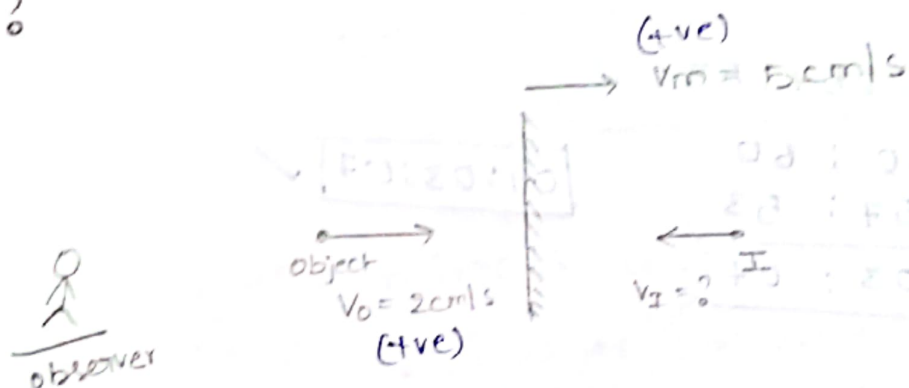
$$V_I = 2(-5) - 2$$

$$V_I = -10 - 2$$

$$V_I = -12 \text{ cm/s}$$

> (Q) An object moves 2 cm away from the observer and mirror moves 5 cm away from the observer then the velocity of the image is?

(A)



$$V_I = 2V_m - V_o$$

$$= 2(5) - 2$$

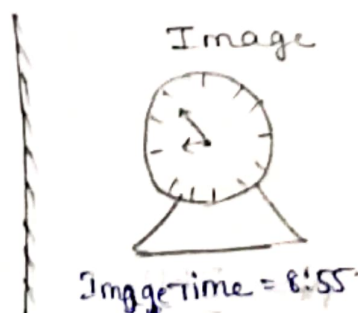
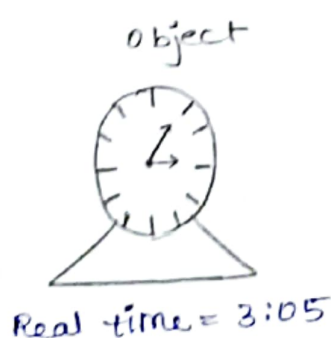
$$= 10 - 2$$

$$V_I = 8 \text{ cm/s}$$

* Angular clock images in mirror (Plane) :-

> (Q) In angular clock real time 3:05. Find image in plane mirror?

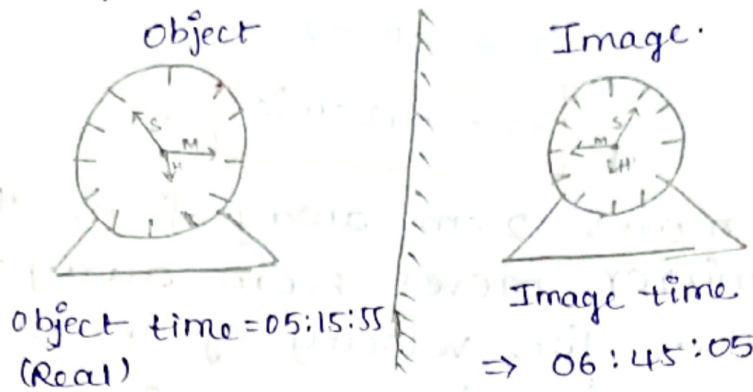
(A)



R.K sir's
Trick :-

$$\begin{array}{r} 11:60 \\ (-) 3:05 \\ \hline 8:55 \end{array}$$

> (Q) The real time in angular clock is 5hr:15min:55sec.
The image in mirror.



Trick:

$$\begin{array}{r} 11:60:60 \\ \ominus 5:15:55 \\ \hline 6:45:05 \end{array}$$

Ex:- 2:57:53

$$\ominus \begin{array}{r} 11:60:60 \\ 2:57:53 \\ \hline 9:03:07 \end{array}$$

$$\boxed{09:03:07} \checkmark$$

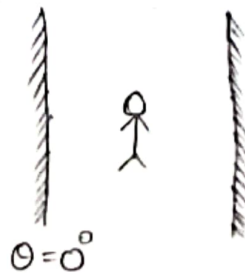
* No. of images in two plane mirrors :-

Case-①:-

> When two plane mirrors arranged parallel to each other & object arranged b/w them. ~~The observe~~
It produce infinite no. of images. The human eye having limiting resolving power. We cannot see infinite no. of images.

> The human eye limiting resolving power

$$(R.p) = \frac{1}{60^\circ} = 1'$$

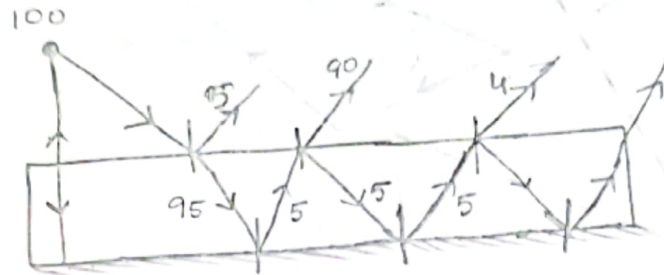


$$N = \frac{360^\circ}{\theta}$$

$$N = \frac{360^\circ}{0^\circ} = \infty$$

> * When two plane mirrors arranged parallel to each other second image appears brightest image. ** previously asked.

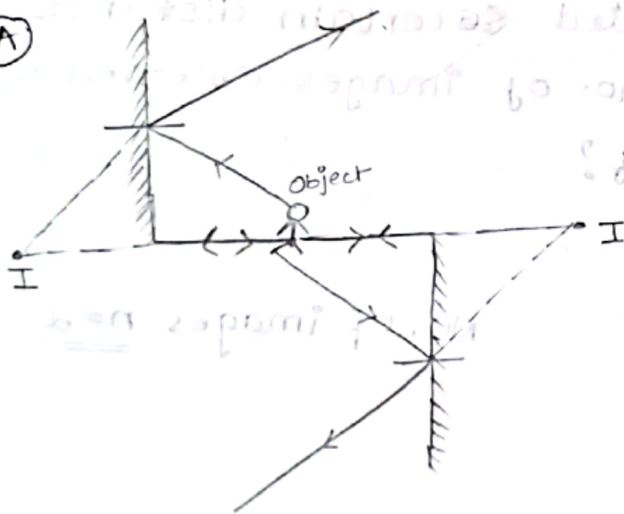
Reason: According to the property of the light, the refracted ray consist more bright & reflected light consist minimum bright.



> (Q) Two plane mirrors arranged as show in figure the no. of images observed by the

Observer.

(A)



(A) 4

(B) 3

(C) 2

(D) 1

Problem 1:-

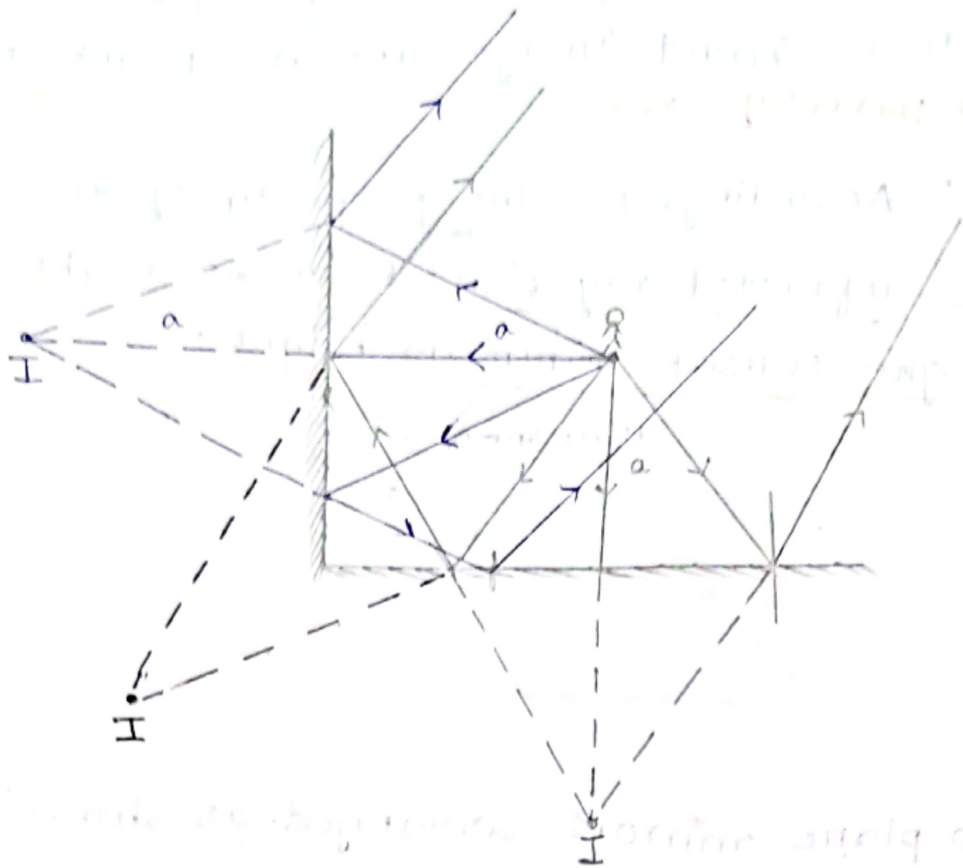
Exa Adv:-

> (Q) Two plane mirrors arranged 120° to each other. The object arranged b/w the mirrors as show in figure. No. of images observed by the observer by itself.

(A)

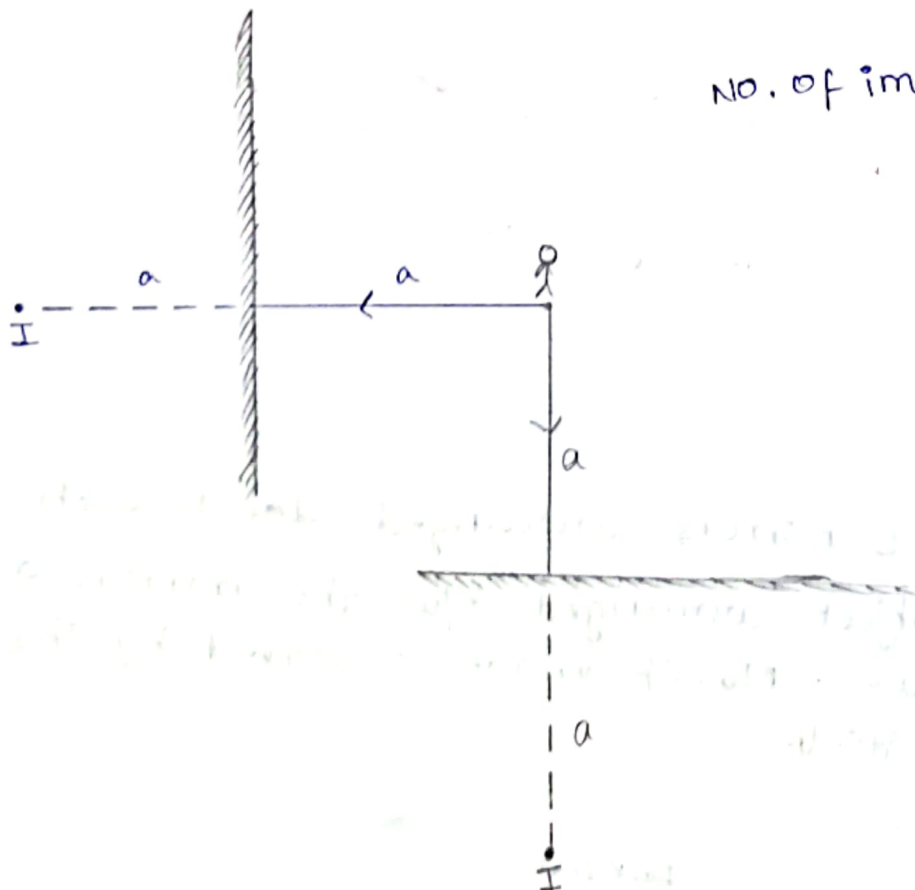
Answer

Back side.



No. of images $n=3$

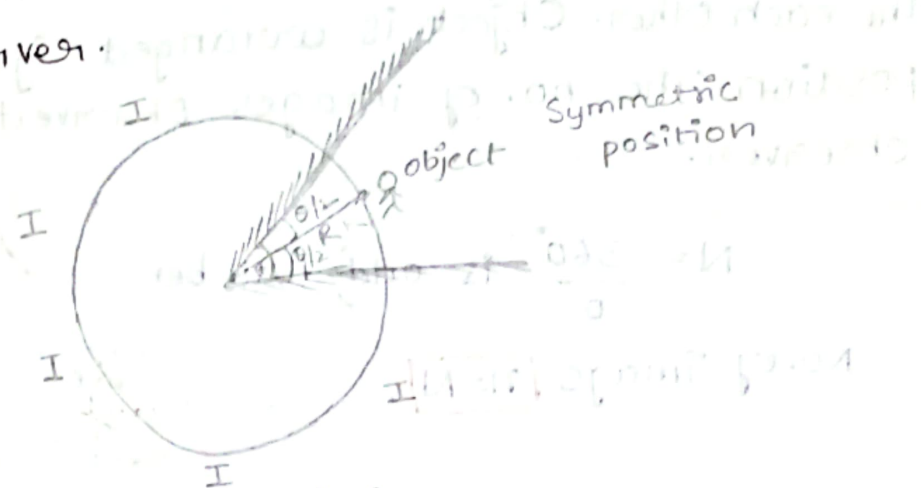
Ques $\rightarrow$ (Q) Two plane mirrors arranged $\perp$ to each other and separated by certain distance as show in figure no. of images observed by the observer by itself?



No. of images $n=2$

> (Q) Let two plane mirrors makes an angle θ with each other. Object arranged with symmetric position. The no. of images observed by the observer.

Main:



$$N = \frac{360^\circ}{\theta} \text{ is even number}$$

$$\text{no. of image } n = N - 1$$

Ex:- $\theta = 60^\circ$

$$N = \frac{360}{60} = 6$$

$$n = N - 1 \Rightarrow n = 6 - 1 = 5 \quad \boxed{n=5}$$

⇒ Case-2 :-

(Q) Two plane mirrors makes an angle θ with each other. Object is arranged asymmetric position. The no. of images observed by the Observer?

(A)

Even number:



asymmetric position

$$N = \frac{360}{\theta} \text{ is even number}$$

$$\text{no. of image}$$

$$n = N - 1$$

Odd number:

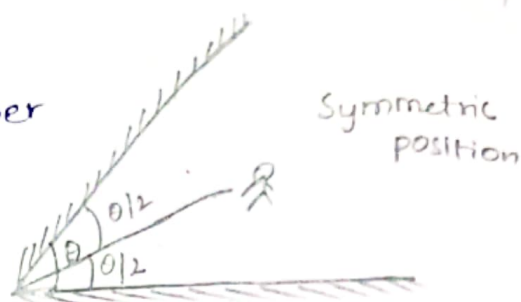
$$N = \frac{360}{\theta} \text{ (Back side).}$$

* Case - (3) :-

> (Q) Two plane mirrors makes an angle θ with the each other. Object is arranged Symmetric Position. The no. of images observed by the Observer.

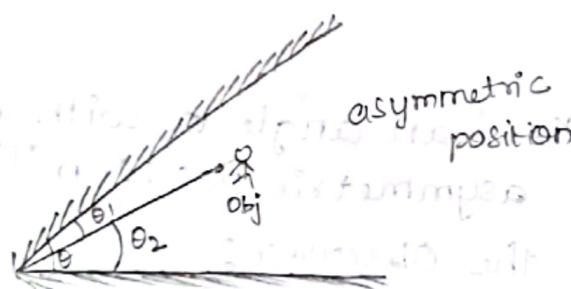
$$N = \frac{360^\circ}{\theta} \text{ is odd number}$$

$$\text{No. of image } n = N$$



* Case - (4) :-

> (Q) Two plane mirrors makes an angle θ and object arrange asymmetric position. The no. of images observed by the observer by itself.



$$N = \frac{360}{\theta} \text{ is odd number}$$

$$\text{No. of image } n = N - 1$$

* Case - (5) :-

> (Q) Two plane mirrors makes an angle θ and object arranged b/w them no. of images observed by the observer.

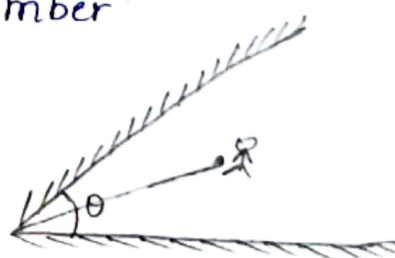
(A)

$$N = \frac{360}{\theta} = \text{Fractional number}$$

$$n = \text{Integer}$$

$$\text{Ex :- } N = \frac{360}{55} = 6.54$$

$$\text{No. of images } (n) = 6$$



* Note :- After reflection, all extended light rays meet together it form the image but any one of the light ray missing image doesnot formed.

> ~~Q~~ (Q)

The angle b/w two plane mirrors 70° . Object arranged at symmetric position. No. of images observed by the observer.

Given, $\theta = 70^\circ$

$$N = \frac{360}{\theta}$$

$$N = \frac{360}{70} \div 5.1$$

No. of images $\boxed{n=5}$ ✓

> (Q) Angle b/w two plane mirrors is 90° . Object arranged Symmetric position. No. of images observed by the Observer.

Given, $\theta = 90^\circ$

$$N = \frac{360}{\theta}$$

$$N = \frac{360}{90} = 4$$

$$N = 4 \Rightarrow \text{(Even)}$$

$$n = N - 1$$

$$n = 4 - 1 = 3$$

$$\boxed{n=3} \quad \checkmark$$

30/03/2024 (Sat):

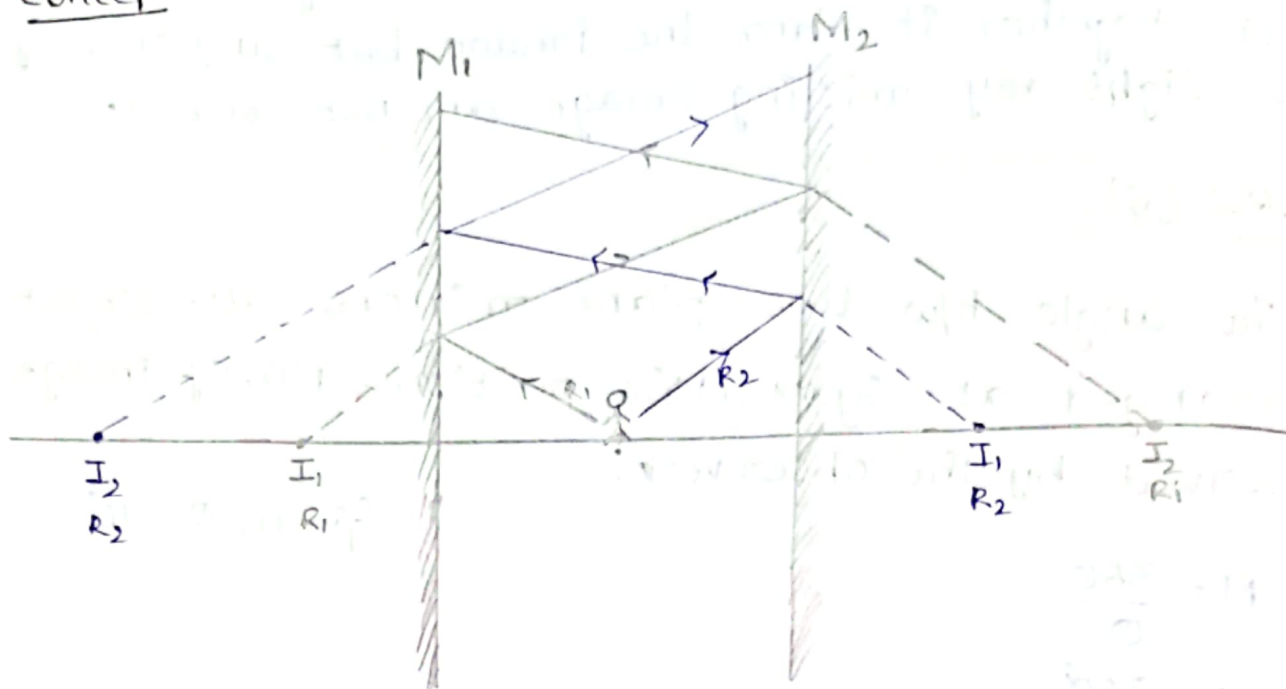
(Q) Two

> ~~Two~~ plane mirrors separated by the distance 10 m. An object arranged 4 m from the first mirror. Find positions of the images in plane mirrors?

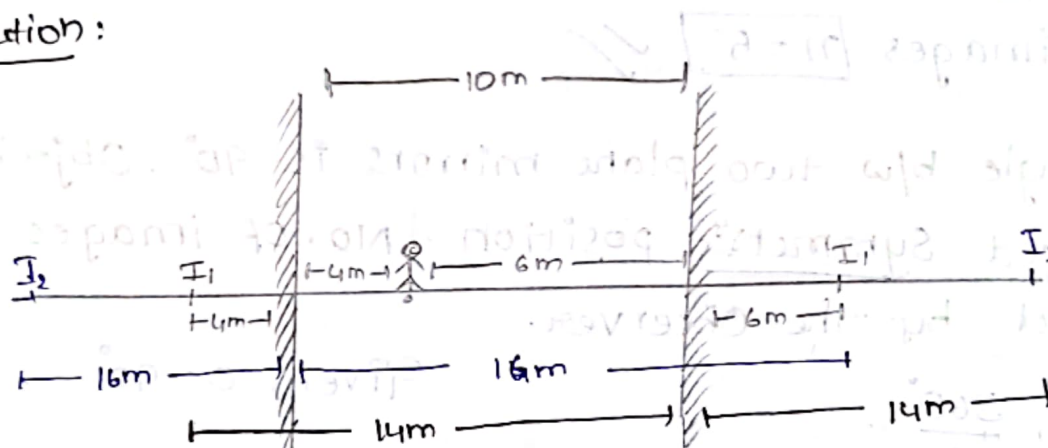
(A)

Backside

Concept:

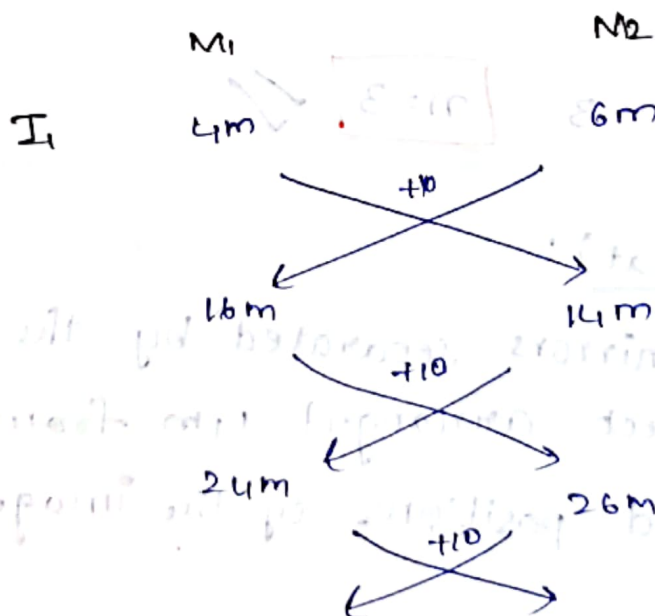


Solution :



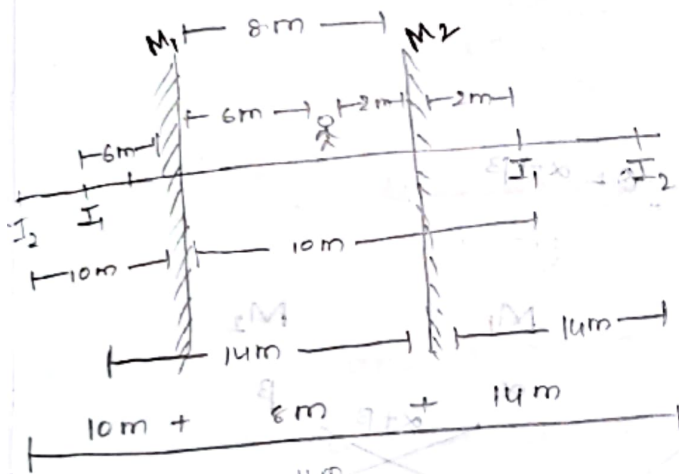
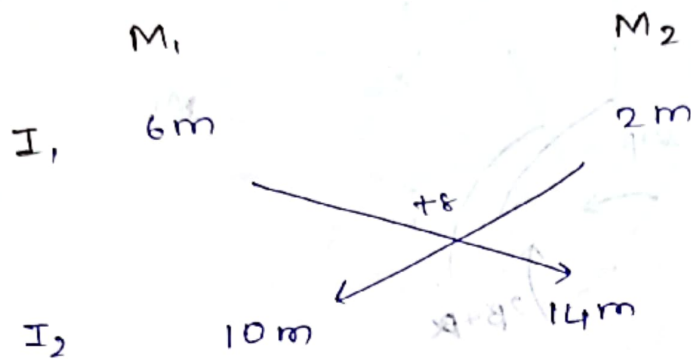
R.K. Sir Trick :-

Cross
Cross
Method:-



> (Q) Two plane mirrors separated by distance 8m. Object arranged at a distance 6m from the first mirror. Find the distance b/w second image in first mirror to second image in second mirror.

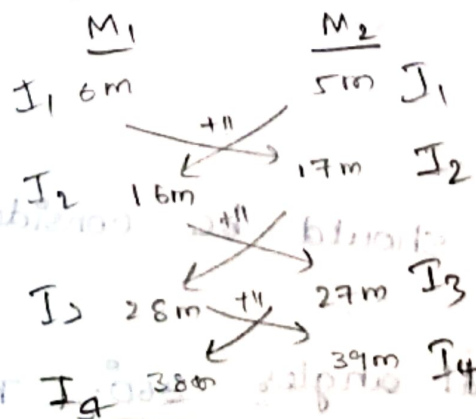
(A)



$$\Rightarrow \boxed{32m = d} \checkmark$$

H.W:-

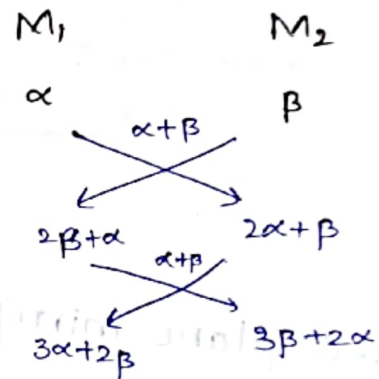
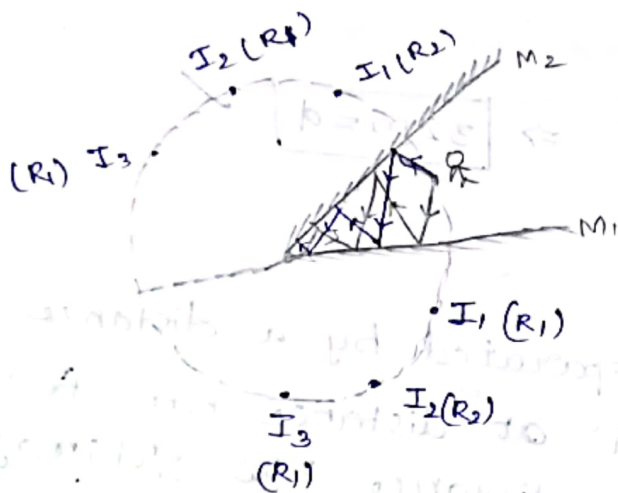
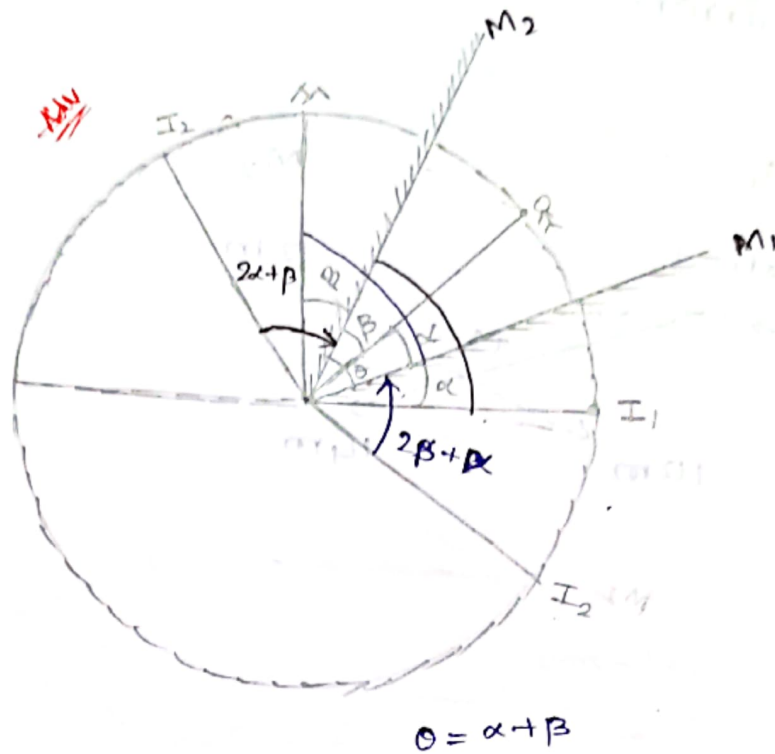
> (Q) Two plane mirrors separated by a distance 11m. Object arranged at distance 5m from the second mirror. Find distance b/w 3rd image in first mirror to 4th image in second mirror.



$$\boxed{d = 78m} \checkmark$$

> (Q) Two plane mirrors makes an angle θ with each other. An object arranged b/w the plane mirrors as shown in figure. Find no. of images observed by the observer.

(A)



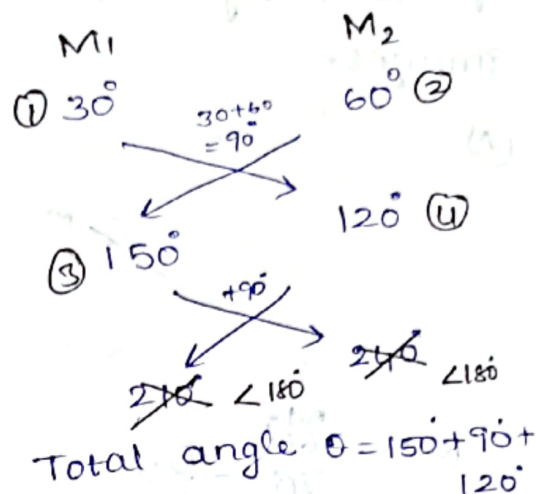
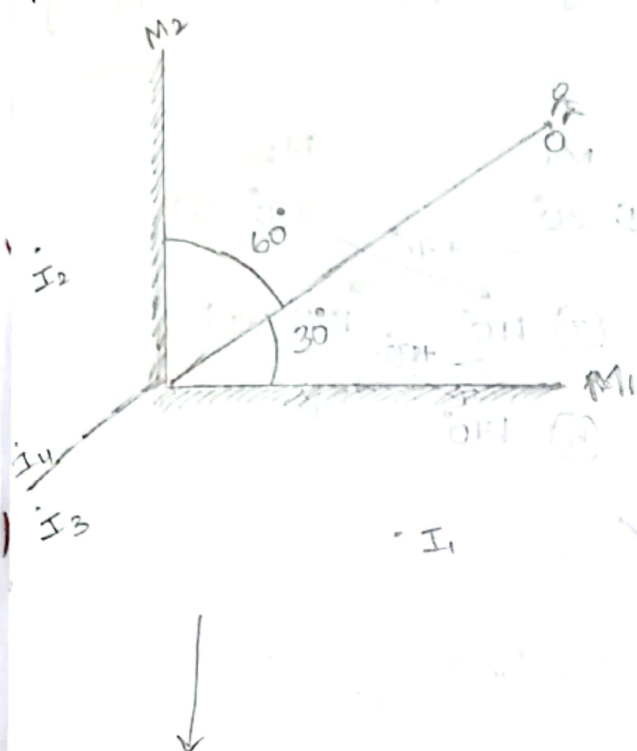
* Final angle $< 180^\circ$
 * more than 180° no Image on screen.

* Note :- (VVI) ***

→ The final angle should be considered less than 180° .

→ The sum of final angles 360° . The no. of images observed by the observer $n = N - 1$

> (Q) Two plane mirrors are to each other object arranged, b/w the mirrors as shown in figure. No. of images observed by the observer.

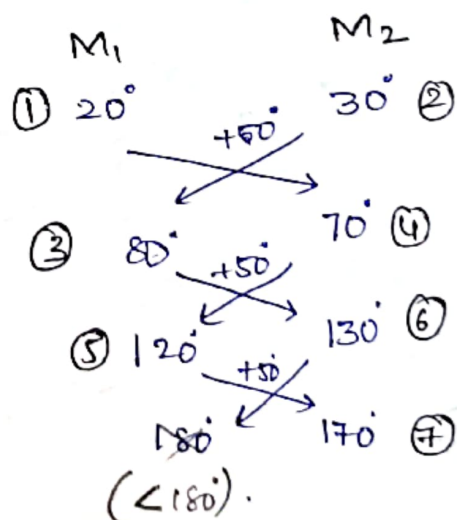
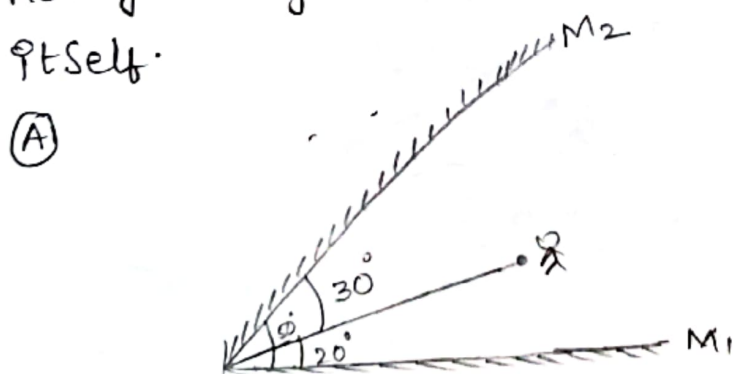


$\theta = 360^\circ$
No. of images $n = 4 - 1$

$$\boxed{n = 3}$$

* Note :- Image 3 and 4 overlapping with each other.

> (Q) Two plane mirrors makes an angle 50° object is arranged as shown in figure. Find no. of images observed by the observer by itself.



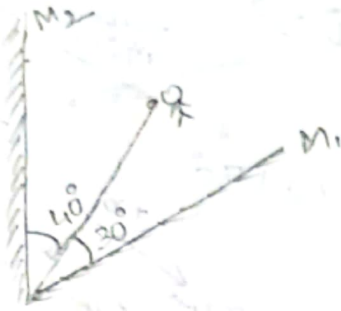
$$N = \frac{360^\circ}{\theta}$$

$$N = \frac{360^\circ}{50^\circ} = 7.2$$

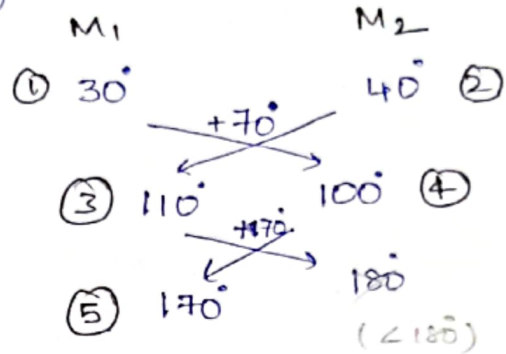
no. of images $(n) = 7$.

> (Q) Two plane mirrors makes an angle 70° . An obj^o arranged ^{blw the mirror} as shown in figure. Find position of the images & no. of images. Find overlapping images.

(A)



$$\theta = 70^\circ$$



$$N = \frac{360}{70} = 5.1$$

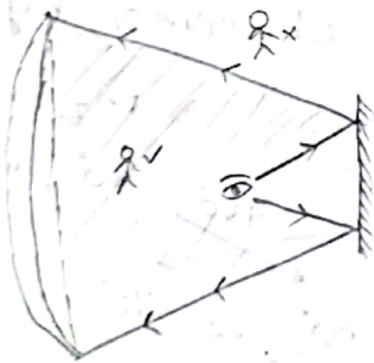
$$\text{no. of images (n)} = 5. \checkmark$$

* Field of View :-

→ After reflection, the region covered by the two extreme light rays is called Field of view.

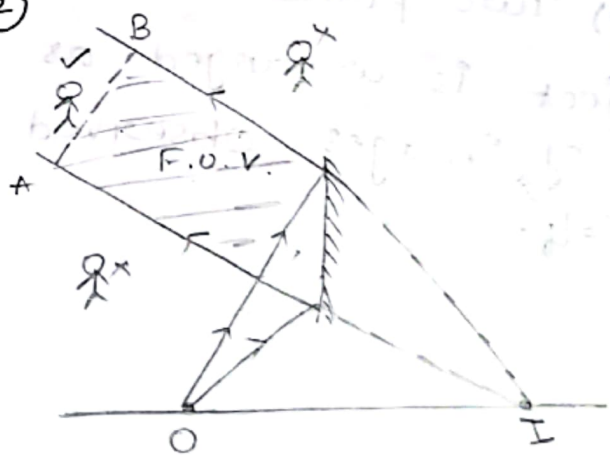
Ex:

(1)

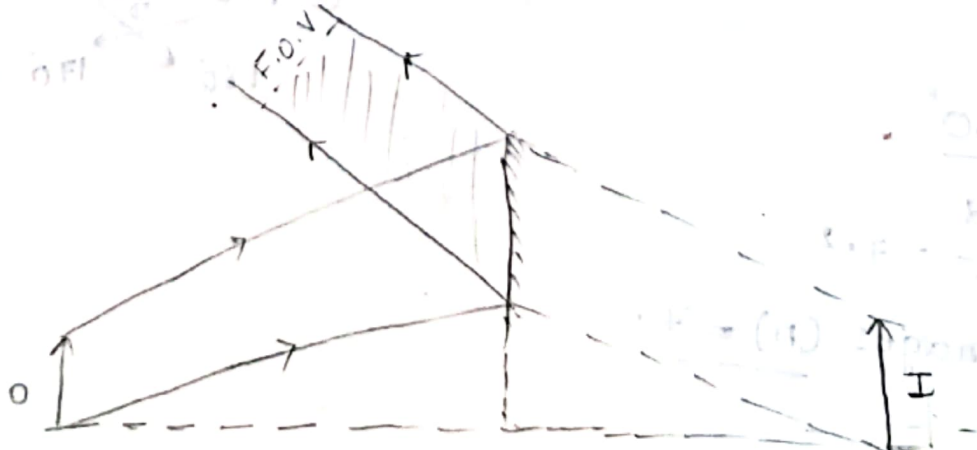


Field of view

(2)

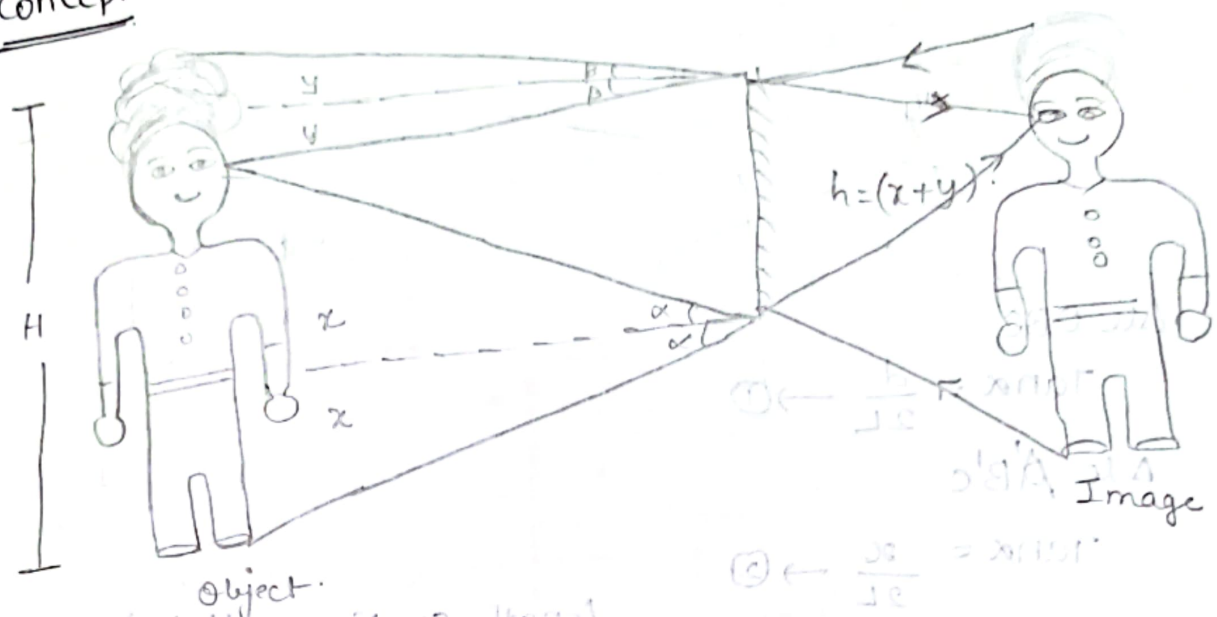


(3)



> (Q) A man heights 6-feet. At given position, find min. size of the mirror to see full image by itself.

concept :-



Object.
 $H = 2y + 2x$

$$H = 2(x+y)$$

length of mirror (h) = $x+y$

$$H = 2h$$

$$h = \frac{H}{2}$$

→ Solution:-

Minimum length of the mirror (h) = $\frac{H}{2}$
 $= \frac{6}{2} = 3$ feet.

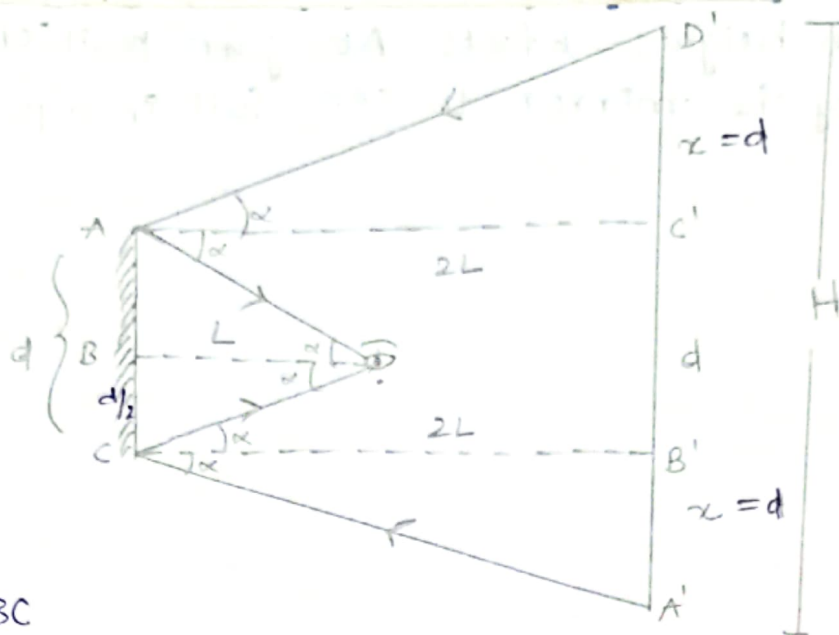
0

> (Q) An object arranged at the centre of the room at a distance 'L' and length of the mirror d. Find max. length of the wall observed by the observer by itself.

(A)

Backsion.

$$\frac{L}{d} = \frac{x}{L} \Rightarrow \frac{x}{L} = \frac{1}{d} \Rightarrow \frac{x}{L} = \frac{1}{d}$$



Δ ABC

$$\tan \alpha = \frac{d}{2L} \rightarrow (1)$$

Δ A'B'C

$$\tan \alpha = \frac{x}{2L} \rightarrow (2)$$

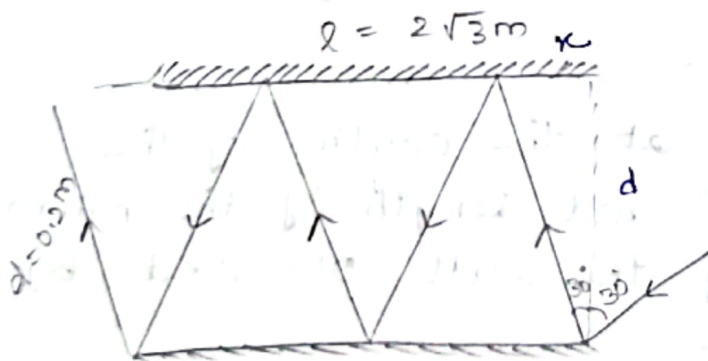
$$\frac{x}{2L} = \frac{d}{2L}$$

$$\boxed{x = d}$$

Length of the wall (H) = $x + x + d$
 $= d + d + d$

$$\boxed{H = 3d}$$

> (Q) Two plane mirrors separated by the distance 0.2 m and length of the each mirror $2\sqrt{3}$ m. It is incident at an angle 30° . It makes multiple reflections. Find no. of reflections before emergent.



$$l = nx$$

$$n = \frac{l}{x}$$

$$\tan 30^\circ = \frac{x}{d}$$

$$\frac{1}{\sqrt{3}} = \frac{x}{0.2} \Rightarrow \frac{1}{\sqrt{3}} = \frac{x}{0.2} \Rightarrow \boxed{x = \frac{0.2}{\sqrt{3}}}$$

$$\text{No. of reflections } (n) = \frac{l}{x}$$

$$n = \frac{2\sqrt{3}}{0.2} \times \sqrt{3}$$

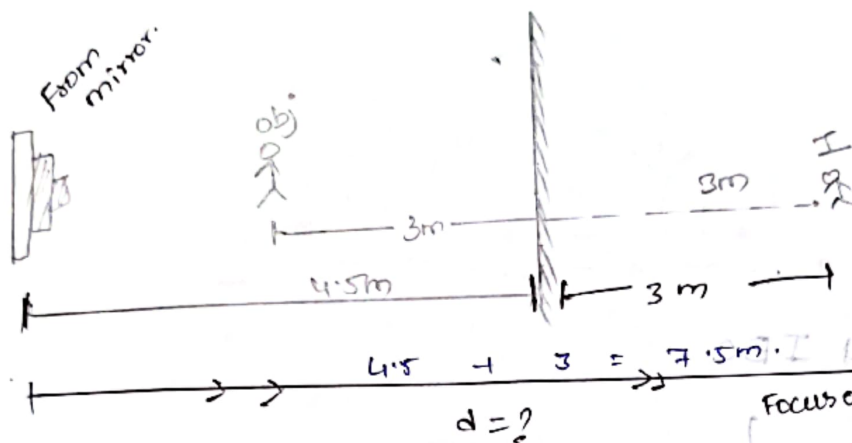
$$n = \frac{3 \times 2}{0.2}$$

$$n = \frac{3 \times 2 \times 10}{2} = 30$$

01/04/2024 :- (Mon) :-

* camera focus on Image *

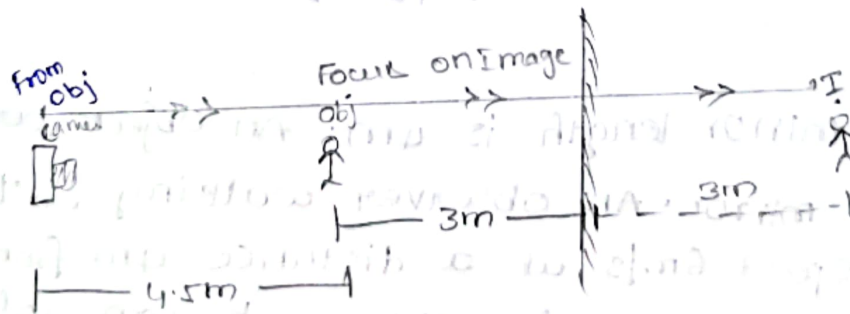
Mains
(Q) An object arranged at a distance 3m from the plane mirror. A camera at a distance 4.5m from the mirror. Find camera focus on image distance is.



Camera focus on image distance $(d) = 4.5m + 3m$
 $d = 7.5m$ ✓

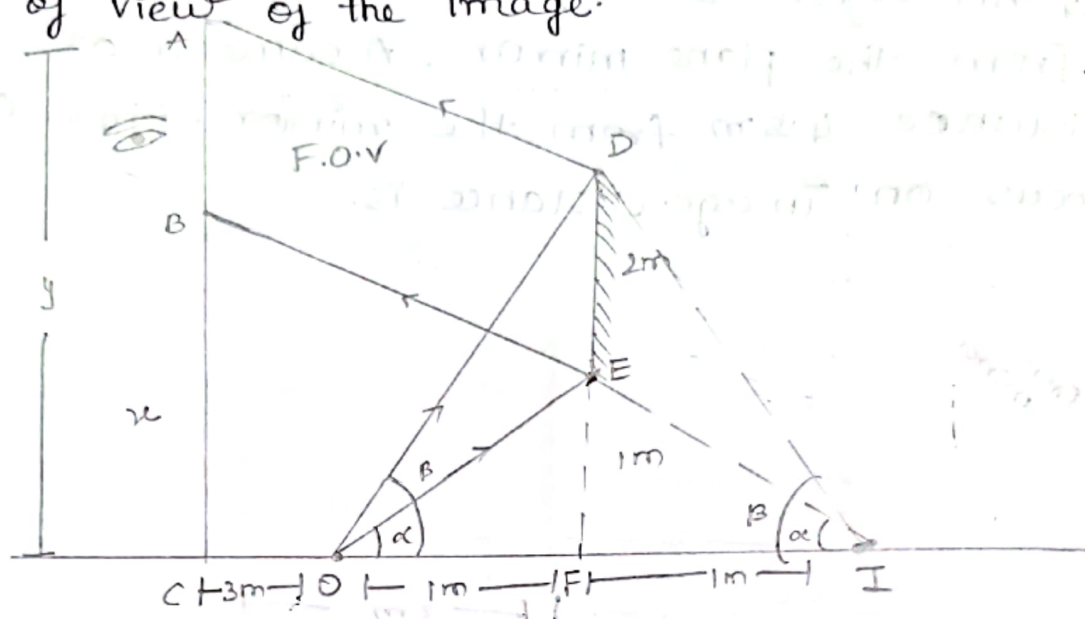
Mains
(Q) An object arranged 3m from the plane mirror. A camera arranged 4.5m from the object. The camera focus on image distance is?

(A)



Camera focus on image distance $(d) = 3m + 3m + 4.5m$
 $d = 10.5m$ ✓

Ans: $\rightarrow$ (Q) An object arranged 1m from the mirror of length 2m. It is arranged at a height 1m. An observer stand at 3m from the object. Find field of view of the image.



From $\triangle IGF$ and IBC

$$\left. \begin{aligned} \tan \alpha &= \frac{1}{4} \\ \tan \alpha &= \frac{x}{5} \end{aligned} \right\} x = 5$$

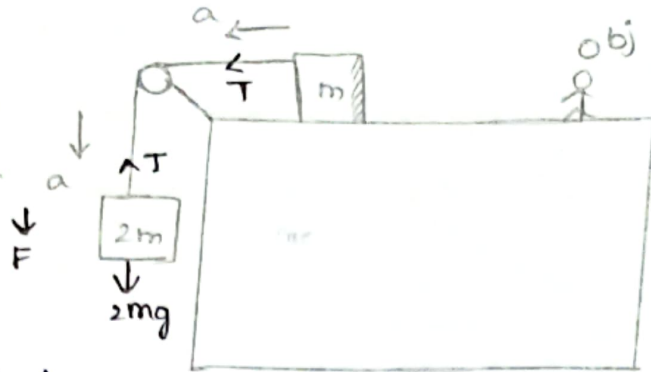
From $\triangle IDF$ and IAC

$$\left. \begin{aligned} \tan \beta &= \frac{3}{4} \\ \tan \beta &= \frac{y}{5} \end{aligned} \right\} y = 15$$

$$\begin{aligned} \text{Field of view on image} &= y - x \\ &= 15 - 5 = 10\text{m} \end{aligned}$$

$\rightarrow$ (Q) A plane mirror length is 4m. An object arranged 2m from the mirror. An observer walking on the road with speed 6m/s at a distance 4m from the mirror. (a) Find how far distance he can able to see the image? (b) How long he can able to see the image?

Q



→ massless string
So, acceleration,
velocity, distance
are same.

F.B.D for mass (2m)

$$F_R = 2mg - T$$

$$2ma = 2mg - T \rightarrow (1) \quad (m=2m)$$

F.B.D for mass (m)

$$T = ma \rightarrow (2)$$

Solve (1) & (2)

$$2ma = 2mg - ma$$

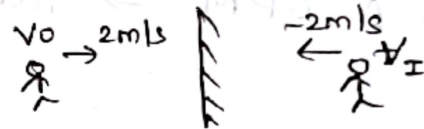
$$3ma = 2mg$$

$$a = \frac{2g}{3}$$

$$a_{IO} = 2a$$

$$a_{IO} = 2\left(\frac{2g}{3}\right)$$

$$a_{IO} = \frac{4g}{3}$$



$$v_I = -2 \text{ m/s}$$

$$v_{OI} = v_0 - v_I$$

$$v_{OI} = 2 - (-2) = 4 \text{ m/s}$$

$$a_{IO} = 10$$

$$H = 3 \times 10$$

$$H = 30 \text{ m}$$

01/04/2024 :-

(Mon) :-

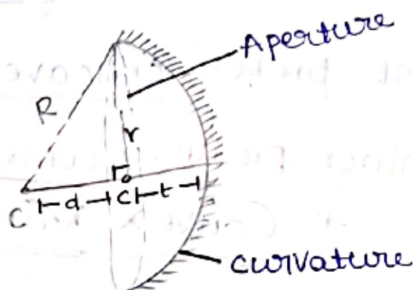
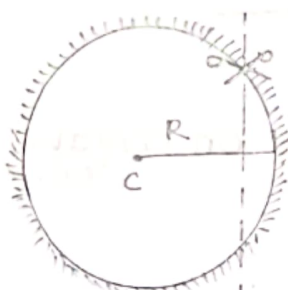
* Spherical Mirror *

Introduction :-

- > Spherical mirrors are two types :-
(i) Concave mirror (ii) Convex mirror

* Concave Mirror *

> A hollow glass sphere with radius R . The outer surface coated with silver and remove small part from the sphere. It is called mirror.



$R \rightarrow$ Radius of curvature

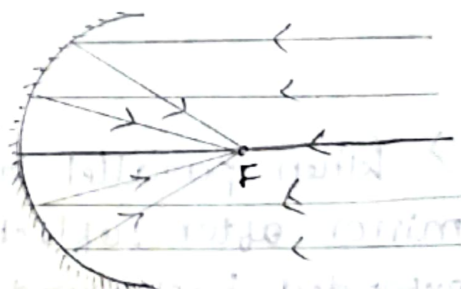
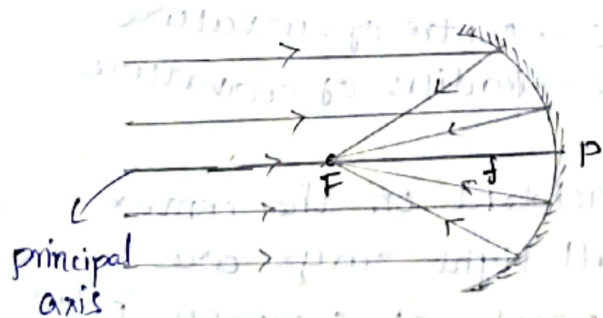
$C \rightarrow$ centre of curvature

$r \rightarrow$ radius of Aperture

when asked
'R' by giving t ,
 d, r

$$R^2 = r^2 + d^2 \Rightarrow R = d + t$$

> When parallel rays incident on the concave mirror after reflection all light rays are meet at common point such point is called Focus or Focal point.



$P \rightarrow$ Pole

$F \rightarrow$ Focus

$PF \rightarrow$ Focal length (f)

* Properties of concave mirror :-

- > In concave mirror, focal length (f) is negative (-ve).
- > In concave mirror, radius of curvature (R) is -ve.
- > In concave mirror, power (P) is +ve $\left[\because P = \frac{1}{f} \right]$.

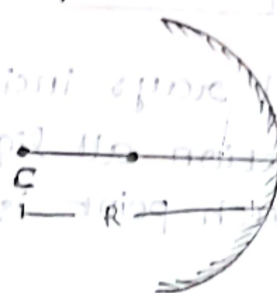
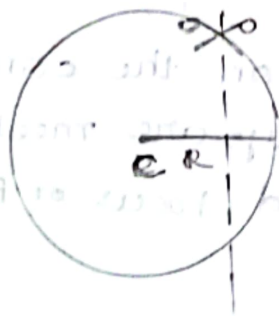
In lens, power $(P) = \frac{1}{f}$

convergent rays

- * > The concave mirror produce real focal point.
- > concave mirror produce less field view.
- > The dentist prefer concave mirror.
- * > concave mirror produce convergent rays on concave mirror.

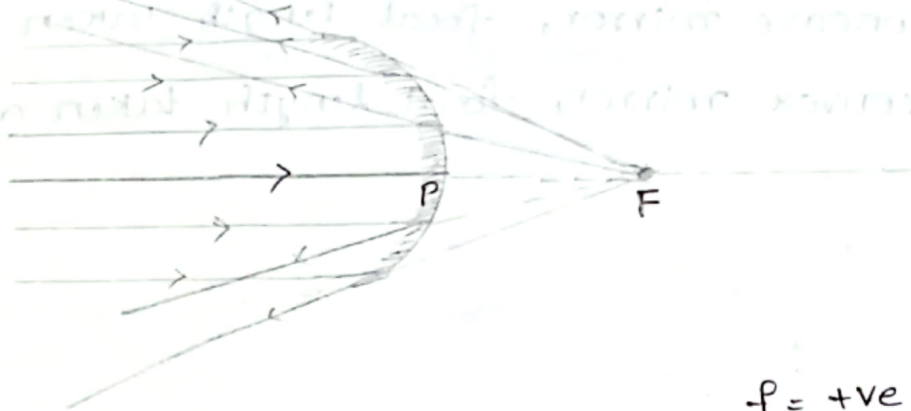
* Convex Mirror *

- > A hollow glass sphere of radius (R) . A small part removed from the sphere and coated inner side of the mirror with silver. It is called convex mirror.



C $\rightarrow$ centre of curvature
R $\rightarrow$ Radius of curvature

- > When parallel rays incident on the convex mirror after reflection all light rays are diverged extended backward and meet at common point called Focus or Focal point or principal focus.



P = pole
 F = Focal point or Focus
 PF = focal length (f)

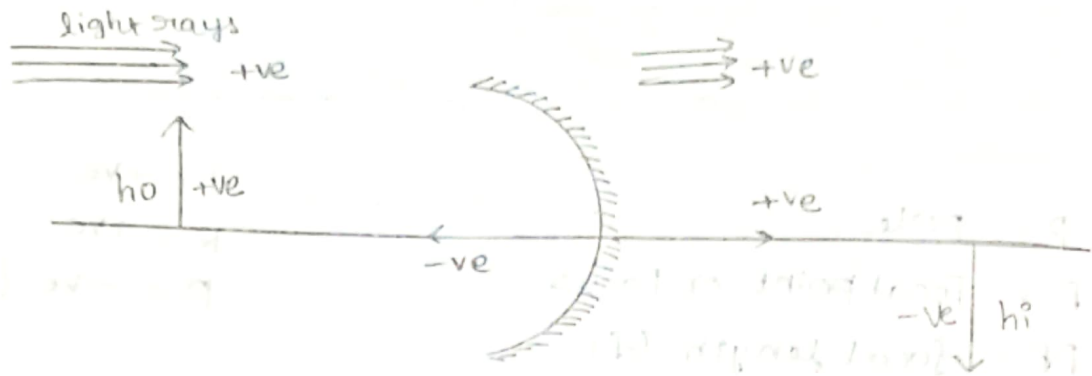
f = +ve
 R = +ve
 P = -ve ($P = \frac{-1}{f}$)

- > In convex mirror, the focal length is (+ve)
- > In convex mirror, the radius of curvature is (+ve)
- > In convex mirror, power is (-ve) ($\because P = \frac{-1}{f}$)
- > It has max. or more field view.
- > It is used in automobiles as a side mirror. (side)
- > * Convex mirror produce divergent rays.

* SIGN CONVENTION :- Board (4m) Q.

- > The direction of the light taken as +ve.
- > All distances ~~are~~ should be measured from the pole.
- > When distance measured opposite to the line direction taken as -ve.
- > When distance measured along the line direction taken as +ve.
- > When distance measured (height) above the principal axis taken as +ve.
- > When distance measured (height) below the principal axis taken as -ve.

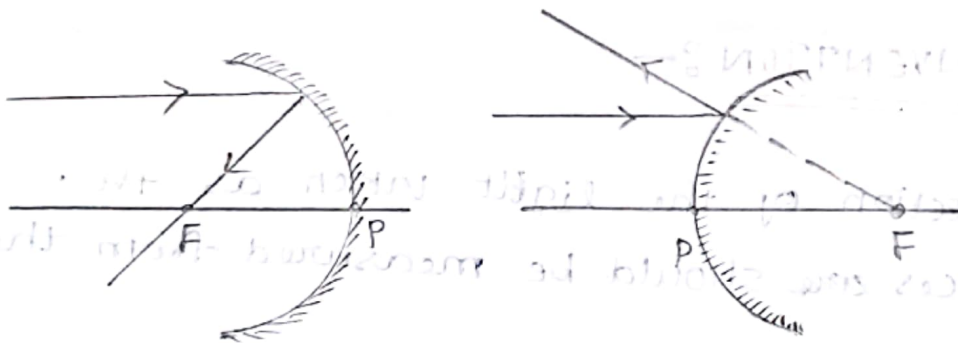
- > The concave mirror, focal length taken as $-ve$.
- > The convex mirror, focal length taken as $+ve$.



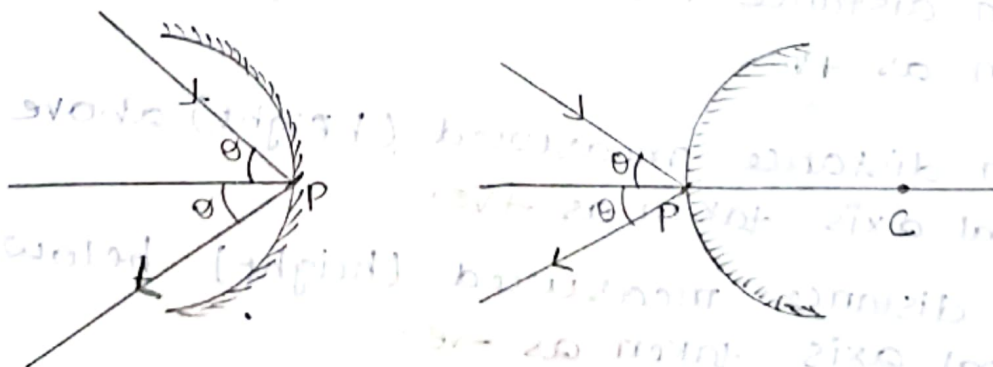
- Object distance (u) = $-ve$
- Image distance (v) = $+ve$
- Object height (h_o) = $+ve$
- Image height (h_i) = $-ve$

* Rules for image formation:-

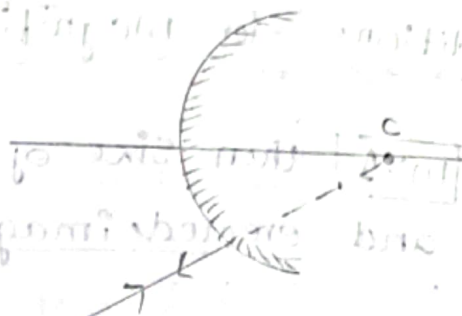
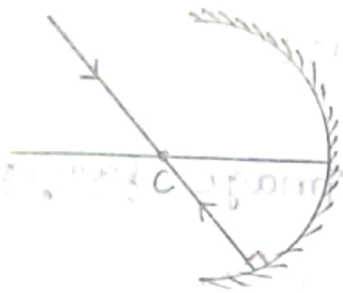
- > When parallel rays incident on the spherical mirror after reflection it passes through the focal point (or) principal focus.



- > When light ray passes through the pole. After reflection it makes same angle.



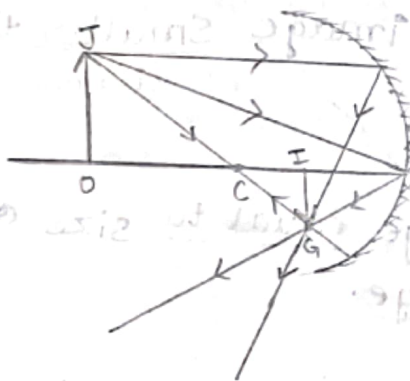
- > When the light ray passes through the centre of ^{after} reflection it retraces its path.



- (Q) > An object arranged at a distance u . The height of the object (h_o) arranged as shown in figure.

Draw a image by using ray diagrams.

(A)



02/04/2024 : (Tue) :-

* Magnification in spherical mirror (m) *

- > The ratio of size of the image to size of the object is called magnification.

- > It is represented by m .

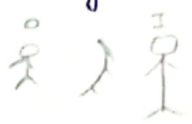
- > Magnification $m = \frac{\text{size of image}}{\text{size of object}}$

- > It has no units & no dimensional formula.

- > The magnification along height is called Transverse magnification (or) lateral magnification

> If magnification measured along the principal axis is called longitudinal magnification.

* Conditions for magnifications:-

① If $m > 1$ then size of the image larger than object and erected image.  (enlarged)

② If $m > -1$ then size of the image larger than object and inverted image.  (enlarged)

③ If $m < 1$ then size of the image smaller than object and erected image.  (Diminished)

④ If $m < -1$ then size of the image smaller than object and inverted image.  (Diminished)

⑤ If $m = 1$ then size of image equal to size of the object and erected image. 

⑥ If $m = -1$ then size of image equal to size of the object but forms inverted image. 

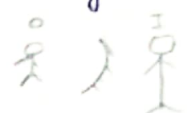
⑦ If $m \gg 1$ the size of image more larger than the size of the object and erected image. 

⑧ If $m \gg -1$ then the size of image more larger than object but inverted image.  Microscopic

⑨ If $m \ll 1$ the size of the image is more smaller than object and erected image. 

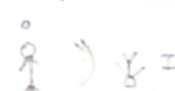
> If magnification measured along the Principal axis is called longitudinal magnification.

* Conditions for magnifications:-

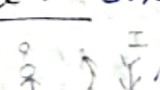
① If $m > 1$ then size of the image larger than object and erected image.  (enlarged)

② If $m > -1$ then size of the image larger than object and inverted image.  (enlarged)

③ If $m < 1$ then size of the image smaller than object and erected image.  (Diminished)

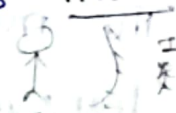
④ If $m < -1$ then size of the image smaller than object and inverted image.  (Diminished)

⑤ If $m = 1$ then size of image equal to size of the object and erected image. 

⑥ If $m = -1$ then size of image equal to size of the object but forms inverted image. 

⑦ If $m \gg 1$ the size of image more larger than the size of the object and erected image. 

⑧ If $m \gg -1$ then the size of image more larger than object but inverted image.  Microscopic

⑨ If $m \ll 1$ the size of the image is more smaller than object and erected image. 

⑩ If $m < -1$ then the size of the image more smaller than object but inverted image.

⑨ & ⑩ $\} \rightarrow$ Telescopic magnification.

* Note :-

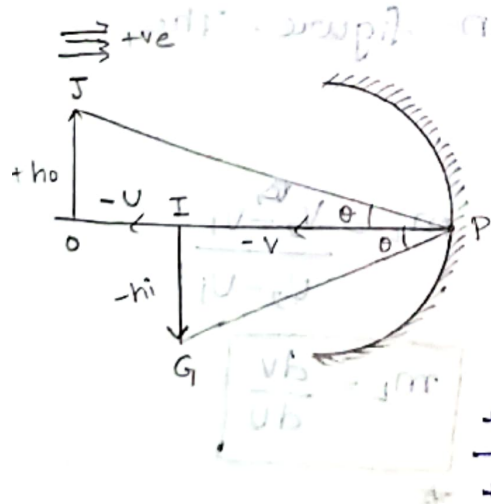
If $m > 1$
 $m > -1$ } Microscopic Magnification

If $m < 1$
 $m < -1$ } Telescopic Magnification.

* Transverse Magnification *

> This is also known as Lateral Magnification.

> Let an object arranged at a distance 'u' from the pole. It form the image at a distance 'v' from the pole. The height of the object 'h_o', it form the image of height 'h_i' as shown in figure.



From the ΔPOI

$$\tan \theta = \frac{+h_o}{-u} \rightarrow (1)$$

From the ΔPIQ

$$\tan \theta = \frac{-h_i}{-v} \rightarrow (2)$$

$$\frac{+h_o}{+u} = \frac{-h_i}{+v}$$

$$\boxed{\frac{h_i}{h_o} = -\frac{v}{u}}$$

Transverse magnification (m) = $\frac{\text{height of the image}}{\text{height of the object}}$

$$\boxed{m = \frac{h_i}{h_o}}$$

VVI ★ $\boxed{m = -\frac{v}{u} = \frac{h_i}{h_o}}$ ★

> Transverse magnification:- The ratio of height of the image to height of the object is called Lateral magnification (or) transverse magnification.

$$m_T = \frac{\text{height of image}}{\text{height of object}}$$

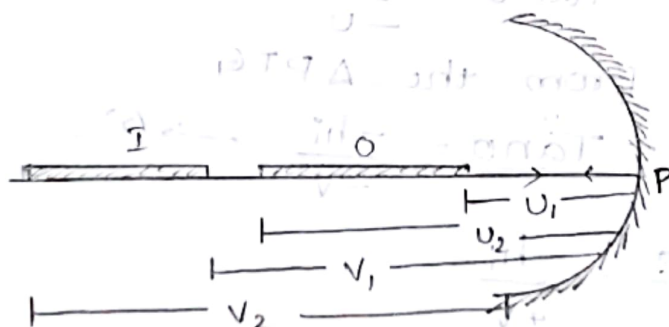
$$m_T = \frac{h_i}{h_o}$$

* Ice-mains * Linear Magnification * (along principal axis).

> Definition:- The ratio of length of the image to length of the object is called Longitudinal or Linear Magnification.

> Explanation:-

Let the object distance U_1 & U_2 , image distance V_1 & V_2 arranged as shown in figure. The linear magnification is:-



longitudinal magnification

$$m_L = \frac{V_2 - V_1}{U_2 - U_1}$$

$$m_L = \frac{dv}{du}$$

* Relation b/w transverse and linear magnification:

⇒ We know mirror equation $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$$\frac{dv}{du} = \frac{v^2}{u^2}$$

> Transverse magnification:- The ratio of height of the image to height of the object is called Lateral magnification (or) transverse magnification.

$$m_T = \frac{\text{height of image}}{\text{height of object}}$$

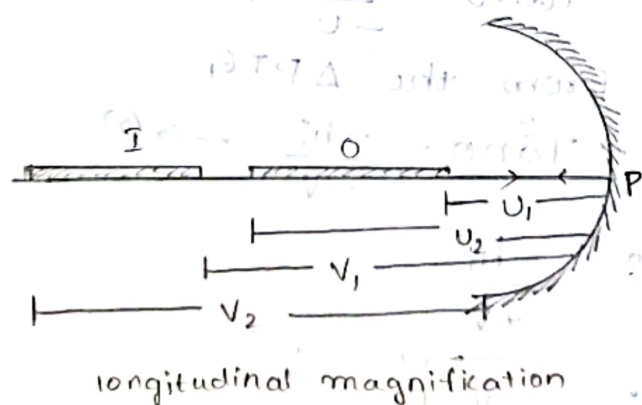
$$m_T = \frac{h_i}{h_o}$$

Jee-Mains *** Linear Magnification * (along principal axis).

> Definition:- The ratio of length of the image to length of the object is called Longitudinal or Linear Magnification.

> Explanation:-

Let the object distance U_1 & U_2 , image distance V_1 & V_2 arranged as shown in figure. The linear magnification is:-



$$m_L = \frac{V_2 - V_1}{U_2 - U_1}$$

$$m_L = \frac{dv}{du}$$

* Relation b/w transverse and linear magnification

⇒ We know mirror equation $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$$\frac{dv}{du} = \frac{V}{U} = m$$

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$v^{-1} + u^{-1} = f^{-1}$$

Differentiation :- $(-1) v^{-2} \cdot dv + (-1) u^{-2} \cdot du = 0$

$$\Rightarrow -\frac{dv}{v^2} - \frac{du}{u^2} = 0$$

$$\Rightarrow \frac{dv}{v^2} = -\frac{du}{u^2} \Rightarrow \frac{dv}{du} = -\frac{v^2}{u^2}$$

$$\Rightarrow \frac{dv}{du} = -\left(\frac{v}{u}\right)^2$$

$$m_L = -\left(\frac{v}{u}\right)^2$$

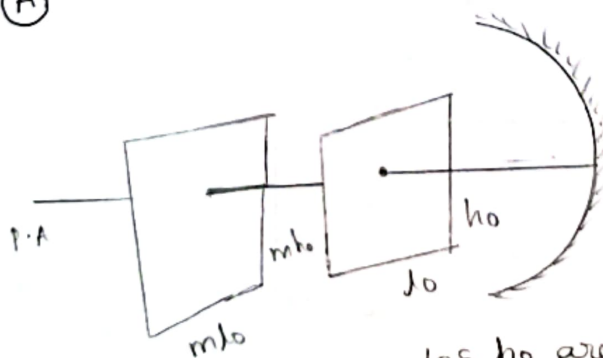
(or)

$$m_L = -(m_T)^2$$

> (Q) A rectangular frame of length l_0 & height h_0 are arranged $\perp$ er to the principal axis. The area of the image?

($\perp$ er $\rightarrow$ transverse mag.)

(A)



l_0 & h_0 are $\perp$ er to P.A.

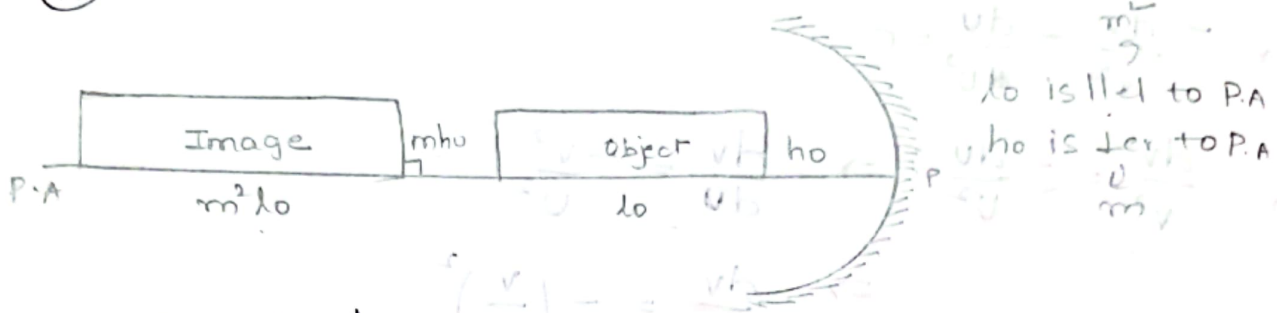
$$A_0 = l_0 \times h_0$$

$$A_i = m l_0 \times m h_0 = m^2 l_0 h_0 = m^2 A_0$$

$$A_i = m^2 A_0$$

> (Q) A rectangular frame of length l_o & height h_o . The length arranged parallel to the principal axis. The magnification of the spherical mirror m . The area of image?

(A)



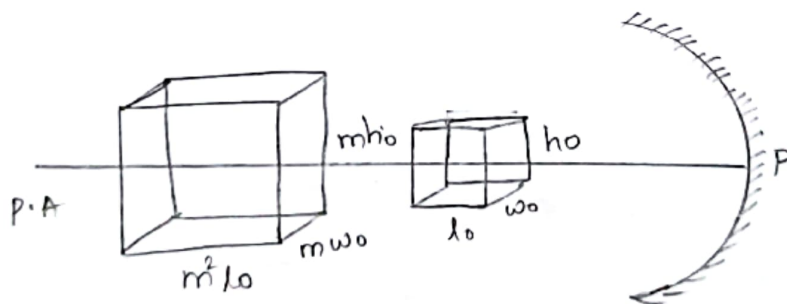
$$A_o = l_o \times h_o$$

$$A_i = m^2 l_o \times m h_o = m^3 l_o h_o$$

$$A_i = m^3 A_o$$

> (Q) A block of length, width, height $\rightarrow l_o, w_o, h_o$ arranged as shown in figure. The magnification of the mirror m . Find volume of the block in image?

(A)



$$V_o = l_o h_o w_o$$

$$V_i = m^2 l_o \times m w_o \times m h_o$$

$$V_i = m^4 l_o h_o w_o$$

$$V_i = m^4 V_o$$

* Relation b/w focal length & radius of curvature

VVS*

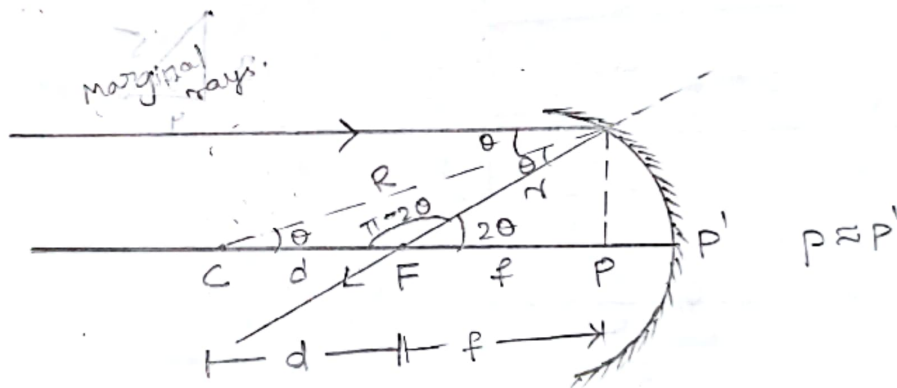
* Adv level:- III:-

> Introduction:

When marginal rays incident on the spherical mirror of radius of curvature (R). After reflection, it passes through the focal point as show in figure.

> A ray which is near to the principal axis is called paraxial rays.

> A ray which is far away from the principal axis is called Marginal rays. $\theta > 5^\circ$.



Sine rule:-

$$\frac{R}{\sin(\pi - 2\theta)} = \frac{d}{\sin\theta} = \frac{r}{\sin\theta}$$

$$\frac{R}{\sin 2\theta} = \frac{d}{\sin\theta}$$

$$\frac{R}{2\sin\theta \cos\theta} = \frac{d}{\sin\theta}$$

$$\boxed{\frac{R}{2\cos\theta} = d}$$

$$\boxed{R = d + f}$$

$$R = \frac{R}{2\cos\theta} + f$$

$$f = R - \frac{R}{2\cos\theta}$$

$$\boxed{f = R \left(1 - \frac{1}{2\cos\theta} \right)}$$

VVS
Adv

$\theta \approx 0^\circ$ (main level).

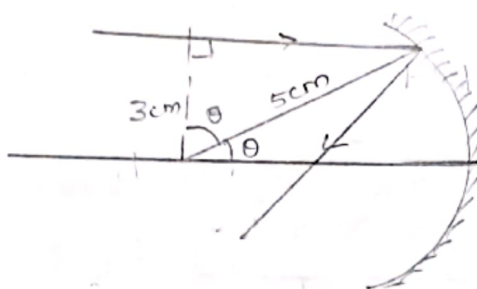
$$f = R \left(1 - \frac{1}{2 \cos(\theta)} \right)$$

$$f = R \left(1 - \frac{1}{2} \right)$$

$$\boxed{f = \frac{R}{2}}$$

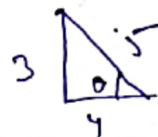
Ex:

> (Q) Marginal rays at height 3cm from the principal axis. It is incident on concave mirror of radius 5cm. Find focal length of mirror.



$$\sin \theta = \frac{3}{5}$$

$$\boxed{\theta = 37^\circ}$$



WKT,

$$d = R \left(1 - \frac{1}{2 \cos \theta} \right)$$

$$d = 5 \left(1 - \frac{1}{2 \cos 37^\circ} \right)$$

$$d = 5 \left(1 - \frac{1}{2 \times \frac{4}{5}} \right)$$

$$d = 5 \left(1 - \frac{1}{\frac{8}{5}} \right)$$

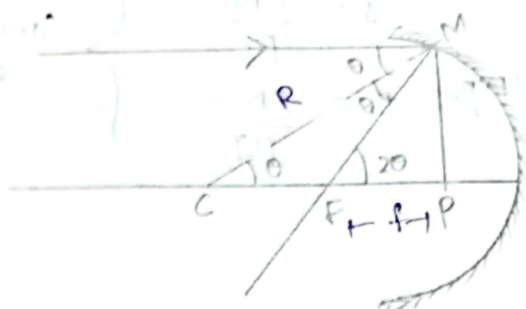
$$d = 5 \left(1 - \frac{5}{8} \right)$$

$$d = 5 \left(\frac{8-5}{8} \right)$$

$$d = 5 \left(\frac{3}{8} \right)$$

$$\boxed{d = \frac{15}{8}} \star$$

Tip & Trick



From ΔCMP (for small angles).

$$\tan \theta \approx \theta = \frac{PM}{PC} \Rightarrow \theta = \frac{PM}{PC} \rightarrow (1)$$

From ΔFPM (for small angles).

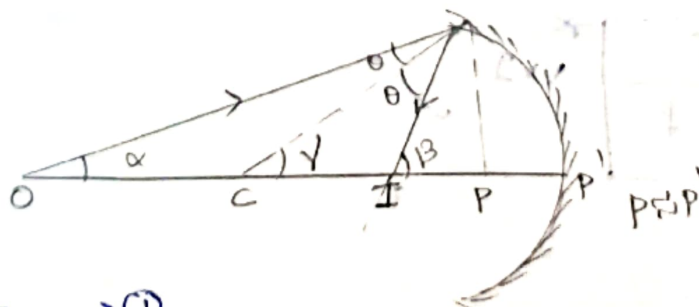
$$\tan 2\theta \approx \frac{PM}{PF} \approx 2\theta$$

$$\frac{PM}{PF} = 2 \left(\frac{PM}{PC} \right) \Rightarrow \frac{1}{f} = \frac{2}{R}$$

$$\Rightarrow \boxed{f = \frac{R}{2}}$$

* Mirror equation for point objects*

> Intro :- Let a point object arranged at a distance u from the pole. It forms the image at a point I at a distance v from the pole. The focal length (f) of the Spherical mirror as shown in figure.



$$PO = u$$

$$PC = R$$

$$PI = v$$

$$f = \frac{R}{2}$$

$$\gamma = \alpha + \theta \rightarrow (1)$$

$$\beta = \gamma + \theta \rightarrow (2)$$

$$\begin{array}{ccc} \epsilon & \epsilon & \epsilon \end{array}$$

$$\gamma - \beta = \alpha - \gamma \Rightarrow$$

$$\boxed{2\gamma = \alpha + \beta}$$

$$\text{From } \Delta ONP \Rightarrow \tan \alpha \approx \alpha = \frac{PN}{PO}$$

$$\text{From } \Delta CNP \Rightarrow \tan \gamma \approx \gamma = \frac{PN}{PC}$$

$$\text{From } \Delta INP \Rightarrow \tan \beta \approx \beta = \frac{PN}{PI}$$

} for small angles.

WKT,

$$2\delta = \alpha + \beta$$

$$2 \left(\frac{PN}{PC} \right) = \frac{PN}{PO} + \frac{PN}{PI}$$

$$\frac{2}{R} = \frac{1}{u} + \frac{1}{v}$$

But,
 $R = 2f$

$$\frac{1}{u} + \frac{1}{v} = \frac{2}{2f}$$

$$\boxed{\frac{1}{u} + \frac{1}{v} = \frac{1}{f}}$$

*Note: Let an object arranged at a distance 'u' from the pole, it form the image at a distance 'v' the focal length of the mirror (f). The image distance

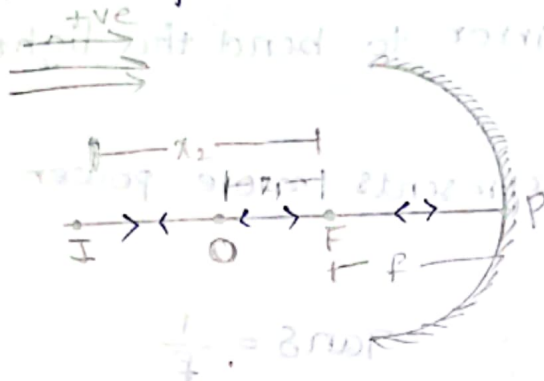
is $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$

$$\frac{1}{v} = \frac{u-f}{uf}$$

$$\boxed{v = \frac{uf}{u-f}}$$

04/04/2024
(Thu) * Newton's formula for Mirror equation

> A spherical mirror of focal length (f). The object distance x_1 from the focal point. The image distance x_2 from the focal point. The relation b/w them :-



$$u = -(f + x_1)$$

$$v = -(f + x_2)$$

$$f = -ve$$

Mirror eqn :-

$$\boxed{\frac{1}{v} + \frac{1}{u} = \frac{1}{f}}$$

$$\frac{1}{f + x_2} + \frac{1}{f + x_1} = \frac{1}{f}$$

$$\frac{1}{f + x_2} = \frac{1}{f} - \frac{1}{f + x_1}$$

$$\frac{1}{f + x_2} = \frac{f + x_1 - f}{f(f + x_1)} \Rightarrow \frac{1}{f + x_2} = \frac{x_1}{f^2 + fx_1}$$

$$\Rightarrow f^2 + fx_1 = x_1(f + x_2)$$

$$\Rightarrow f^2 + fx_1 = fx_1 + x_1x_2$$

$$f^2 = x_1x_2$$

$$\boxed{f = \sqrt{x_1x_2}} \quad \checkmark$$

* Note: The mirror eqn $\left[\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \right]$. The mirror eqn applicable when object moves with constant speed (or) at rest. But mirror eqn not applicable to accelerated objects.

* Power in Spherical Mirror *

> Basic level

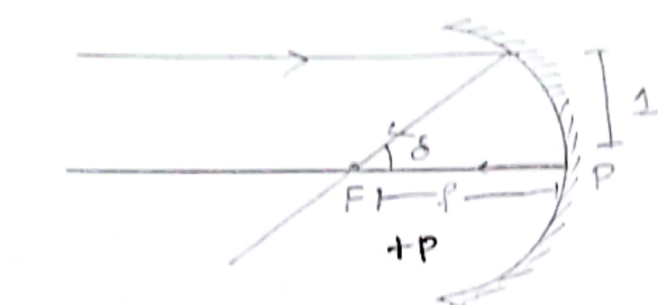
The reciprocal of the focal length is called Power.

(or)

1st level

> The ability of the mirror to bend the light rays is called power.

> More bending effect represents more power but less focal length.



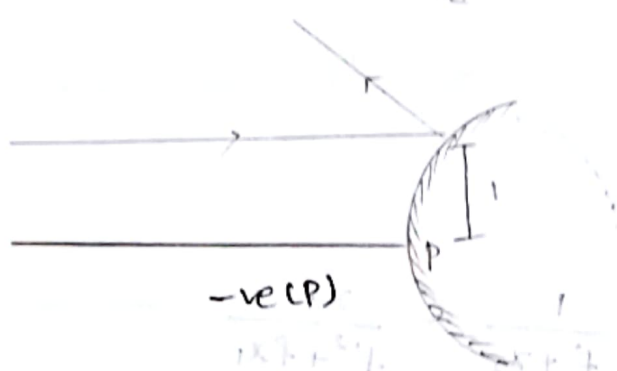
$$\tan \delta = \frac{1}{f}$$

for small angles

$$\tan \delta \approx \delta$$

$$P = \delta = \frac{1}{f}$$

$$P = -\frac{1}{f}$$



Unit:

S.I system: - $\frac{1}{m}$ or Dioptre or D or m^{-1}

C.G.S System: - $\frac{1}{cm}$

$$\frac{1}{cm} = \frac{1}{10^{-2}m} = \frac{100}{m} = 100D = cm^{-1}$$

*** vvi

Note! -> concave mirror has -ve focal length but it has +ve power. It produces convergent rays.

-> convex mirror has +ve focal length but it has -ve power. It produces divergent rays.

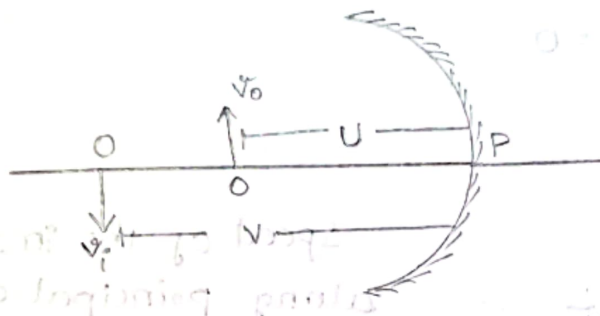
* Speed of the images in Spherical Mirror *

(a) Transverse speed :-

→ When object arranged at a distance U from the pole it form the image at a distance V from the pole.

→ When object moves per to the Principal axis with velocity V_o . The velocity of the image V_i is??

(A)



! Transverse Magnification :

$$m_T = -\left(\frac{V}{U}\right)$$

$$\frac{h_i}{h_o} = -\frac{V}{U}$$

$$h_i = -\left(\frac{V}{U}\right) h_o \Rightarrow \frac{dh_i}{dt} = -\left(\frac{V}{U}\right) \frac{dh_o}{dt}$$

$$V_i = -\left(\frac{V}{U}\right) V_o$$

$V_o \rightarrow$ speed of object

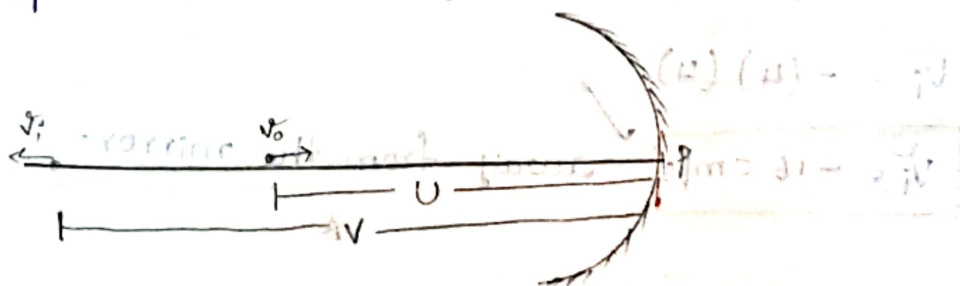
$V_i \rightarrow$ speed of image

$V \rightarrow$ Image distance

$U \rightarrow$ Object distance.

(b) Longitudinal speed :-

→ An object arranged at a distance U it form the image at a distance V . When object moves along the principal axis (parallel) with speed V_o . The speed of the image V_i as shown in figure.



Mirror eqn:

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$v^{-1} + u^{-1} = f^{-1} \quad (\text{Diff. w.r. to time})$$

$$(-1) v^{-2} \cdot \frac{dv}{dt} + (-1) u^{-2} \cdot \frac{du}{dt} = 0$$

$$-\frac{1}{v^2} \cdot \frac{dv}{dt} - \frac{1}{u^2} \cdot \frac{du}{dt} = 0$$

$$-\frac{1}{v^2} \cdot \vec{v}_i - \frac{1}{u^2} \cdot \vec{v}_o = 0$$

$$-\frac{1}{v^2} \cdot \vec{v}_i = \frac{\vec{v}_o}{u^2}$$

$$\vec{v}_i = -\left(\frac{v^2}{u^2}\right) \vec{v}_o$$

$$\vec{v}_i = -\left(\frac{v}{u}\right)^2 \vec{v}_o$$

Speed of the image
along principal axis

$$\vec{v}_i = -\left(\frac{v}{u}\right)^2 \vec{v}_o$$

* Problem:-

Jee-mains

> (Q) A concave mirror magnification is 2. When object moves towards the mirror with speed 4 cm/s. The speed of the image.

Given,
 $m=2$

$v_o = 4 \text{ cm/s}$

$$(A) \quad \vec{v}_i = -\left(\frac{v}{u}\right)^2 \vec{v}_o$$

$$\vec{v}_i = -(m)^2 \vec{v}_o$$

$$\vec{v}_i = -(2)^2 \vec{v}_o$$

$$\vec{v}_i = -(4)(4)$$

$$\vec{v}_i = -16 \text{ cm/s}$$

away from the mirror.

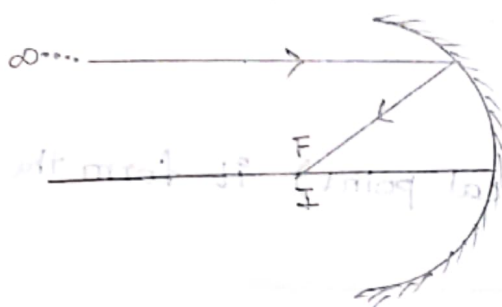


main level * Ray Diagrams :-

(a) Concave mirror :-

(*) When object arranged at infinite distance image formed at focal point. The nature of the image is

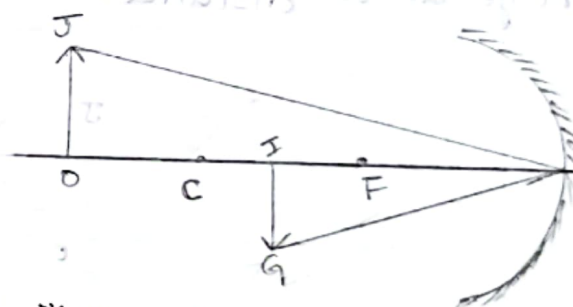
(i) $U = -\infty$
 $V = -F$



- * Real image.
- * point size image.
- * image is inverted.
- * Obj & image are same side.

(ii) $-\infty < U < -C$
 $-C < V < -F$

When obj moves from $-\infty$ to centre of curvature (C) image f/d b/w C and focal point (F). The nature of the image is

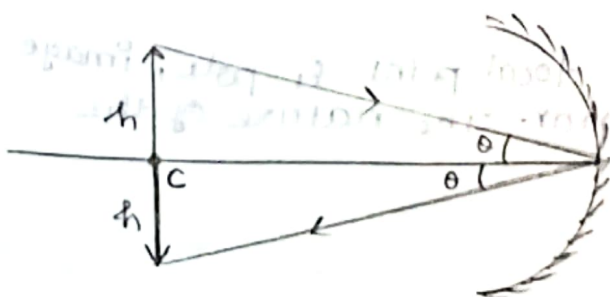


- * Real image
- * inverted, Diminished image
- * Obj and image same side.

* Note:- When Obj move from ∞ to centre the Speed of the Obj much more larger than speed of the image from focal point (F) to centre (C).

(iii) When object arranged at the centre of curvature image also formed at centre of curvature. The nature of the image is :-

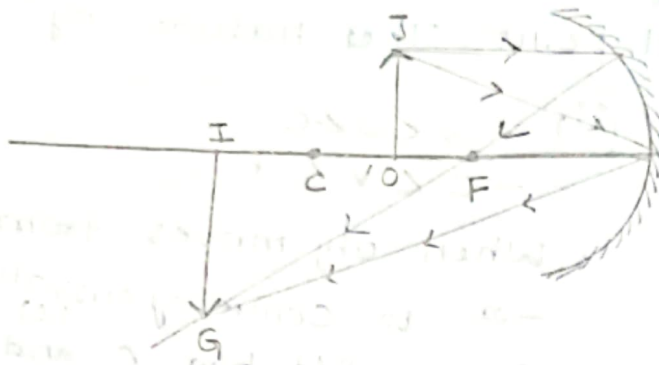
$U = -C ; V = -C$



- * Real image
- * inverted image
- * same size
- * Object and image are same side.

(iv) In this case $-C < U < -F$
 $-C < V < -\infty$

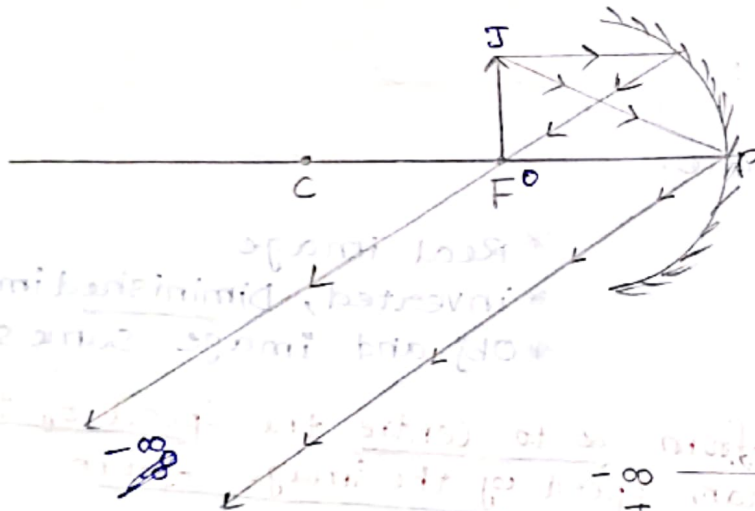
→ When object arranged b/w C and F (focal point)
 image f/d b/w C and ∞ .



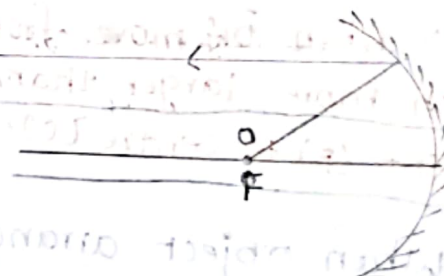
- * Real image.
- * Inverted image.
- * enlarged image.
- * Obj and image are same side.

(v) $U = -F \Rightarrow V = -\infty$

→ When obj arranged at F (focal point) it form the image at ' ∞ ' distance.

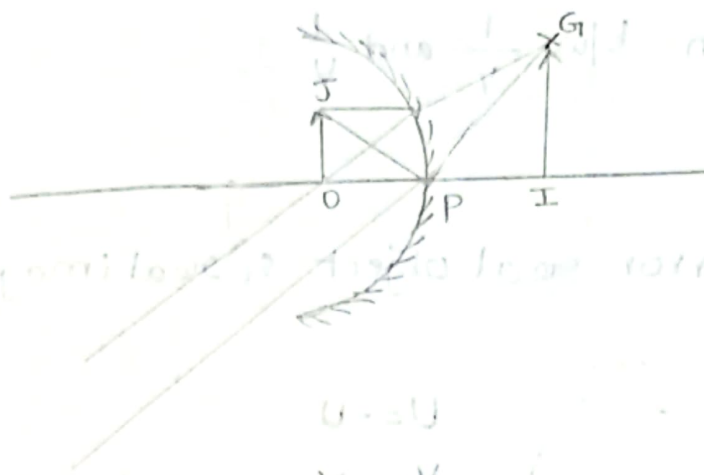


- * Real image.
- * Inverted image
- * Enlarged image
- * Obj & image are on same side.



(vi) $-F < U < -P$
 $-\infty < V < -P$

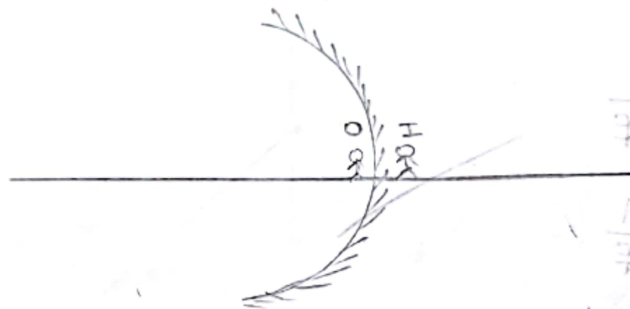
→ When obj. arranged b/w focal point & pole, image formed other side of the mirror. The nature of the image is



- * Virtual image.
- * erect image.
- * enlarged image.
- * Obj & Image are in opposite side.

(vii) $U = -P$
 $V = +P$

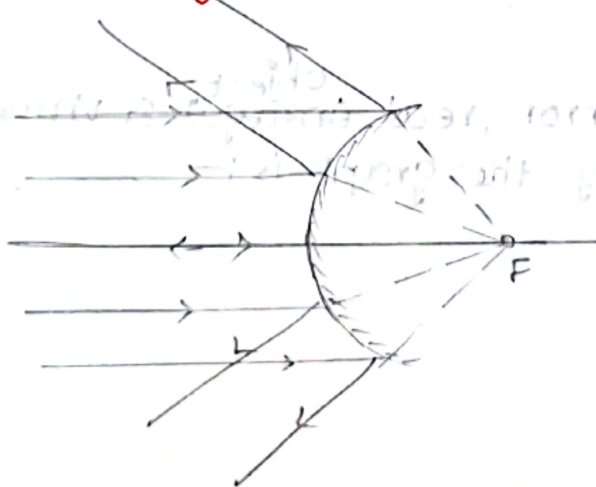
When obj. is placed pole image also formed at the same point. It is act as a plane mirror.



- * Virtual image.
- * Same size.
- * erect image.
- * Obj & image are on opposite side.

(b) Convex Mirror:-

* Note:- In convex mirror, image always virtual image, diminished image and erect image irrespective of position of object.



$\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$

$U = -\infty$

$V = +\infty$

$f = -f$

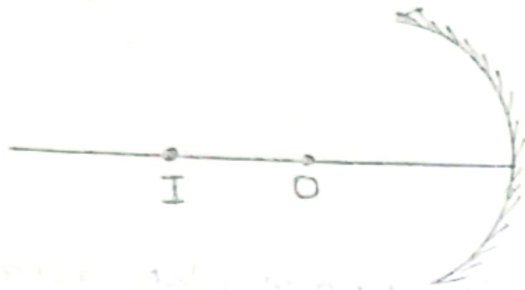
$\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$

$\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$

> A graph drawn b/w $\frac{1}{v}$ and $\frac{1}{u}$

case-1:

For concave mirror real object & real image.



$$U = -U$$

$$V = -V$$

$$f = -ve$$

Mirror eqn.

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

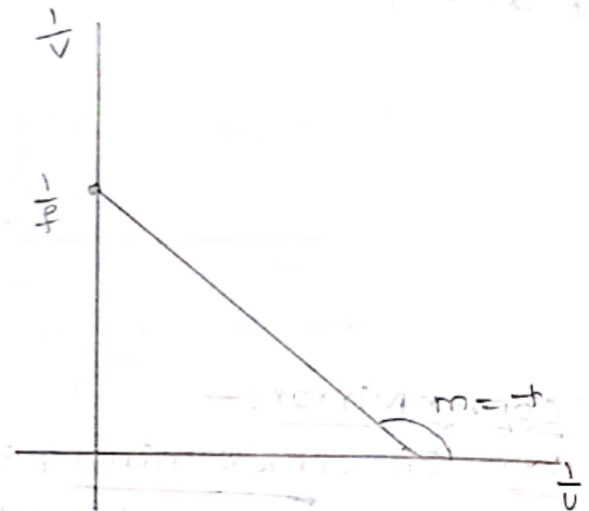
Sign convention:-

$$\frac{1}{-v} + \frac{1}{-u} = \frac{1}{-f}$$

$$\frac{1}{v} = -\frac{1}{u} + \frac{1}{f}$$

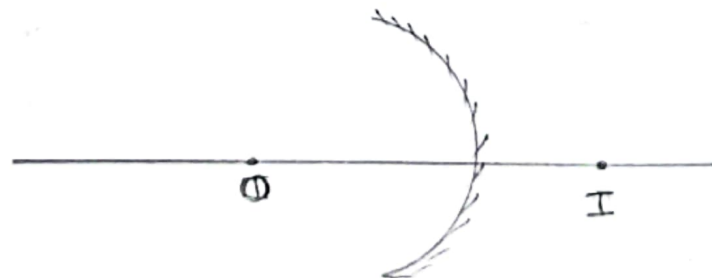
$$\frac{1}{v} = (-1)\frac{1}{u} + \frac{1}{f}$$

$$y = mx + c$$



case-2:

> (Q) For concave mirror real ^{object} ~~image~~ & virtual ^{image} ~~object~~ the nature of the graph is:-



$$U = -U$$

$$V = +V$$

$$f = -f$$

Mirror eqn:-

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

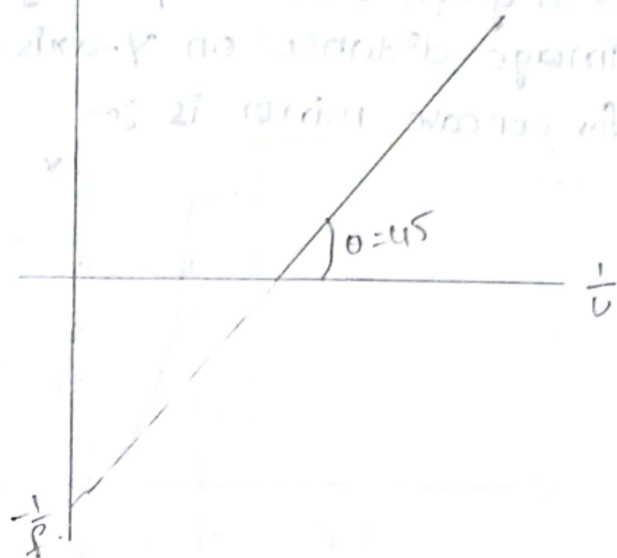
Sign convention:- $\frac{1}{+v} + \frac{1}{-u} = \frac{1}{-f}$

$$\frac{1}{v} = \frac{1}{-f} - \frac{1}{-u}$$

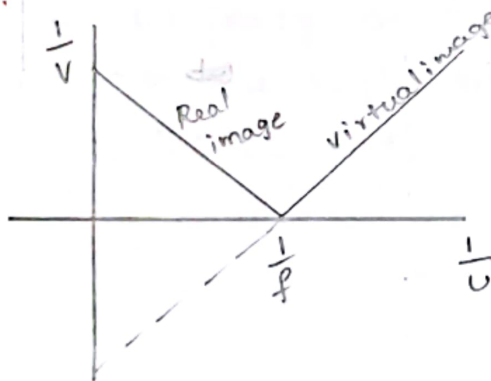
$$\frac{1}{v} = \frac{1}{u} - \frac{1}{f}$$

$$\frac{1}{v} = (1) \frac{1}{u} - \frac{1}{f}$$

$$y = mx + c$$



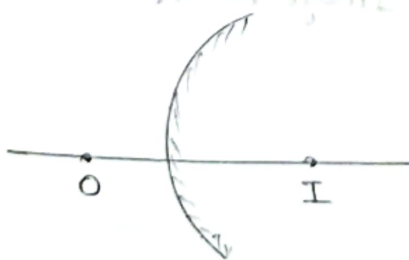
Note:



For concave mirrors

Case-3:-

For convex mirror — real object & virtual image
the nature of the graph is:-

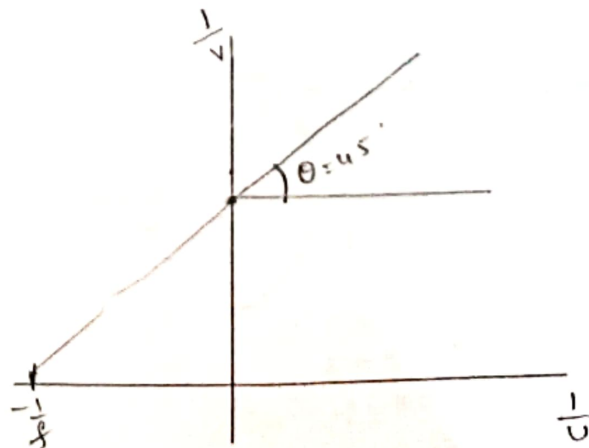


$$u = -u$$

$$v = +ve, f = +f$$

$$\frac{1}{v} + \frac{1}{-u} = \frac{1}{f} \Rightarrow \frac{1}{v} = \frac{1}{u} + \frac{1}{f}$$

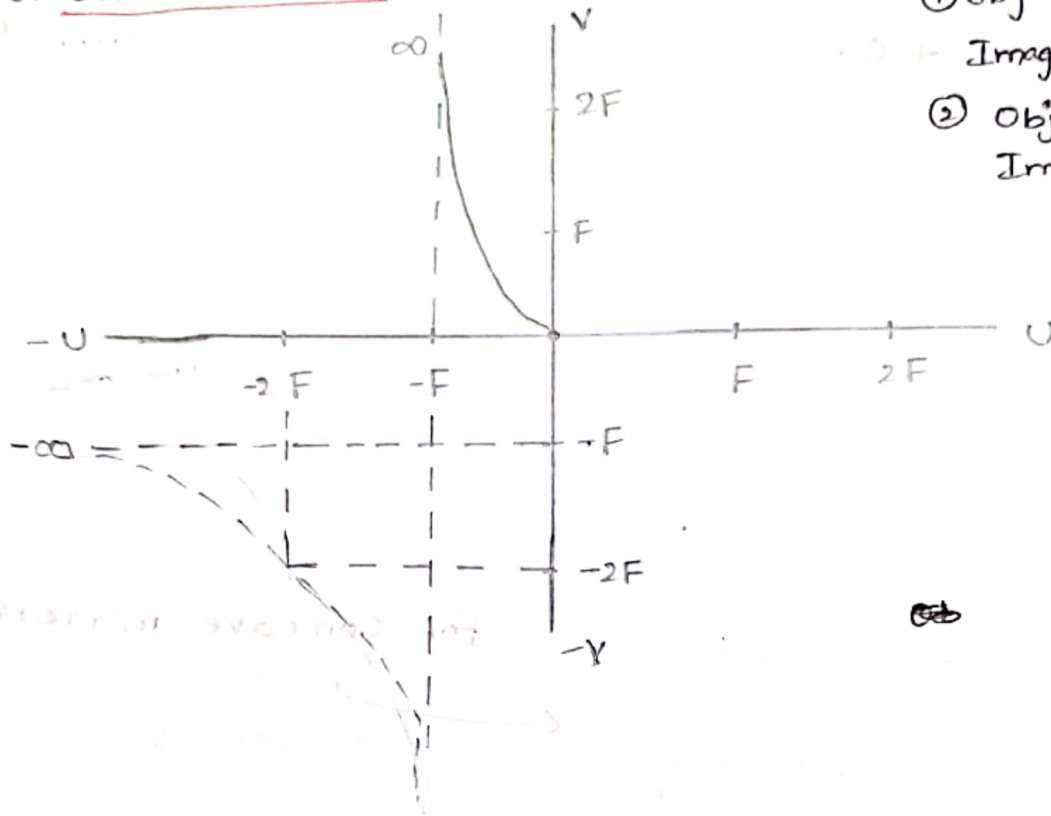
$$y = mx + c$$



* U-V Graphs *

> Case-1:

→ A graph drawn b/w Object distance on X-axis & Image distance on Y-axis. The nature of the graph for concave mirror is :-



① Obj = -F

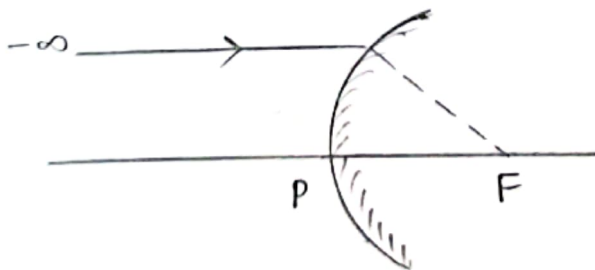
Image = -∞

② Obj = -∞

Image = -F

> Case-2:

A graph drawn b/w U & V along X-axis & Y-axis for convex mirror is :-

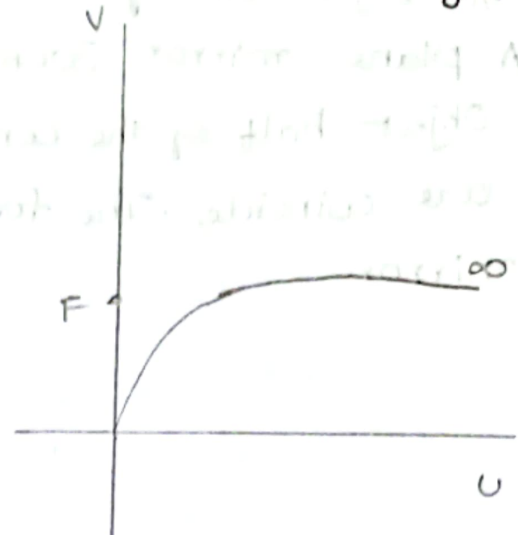
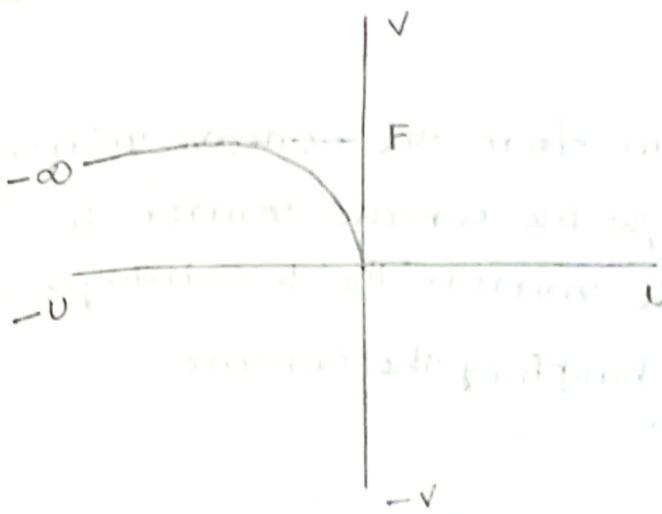


① Obj U = -∞

Image V = +F

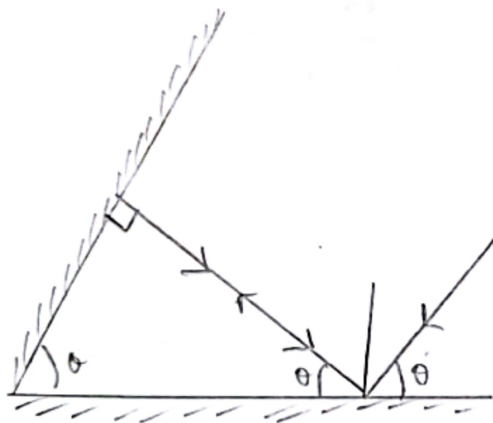
$$\frac{1}{f} + \frac{1}{v} = \frac{1}{u} \quad \leftarrow \quad \frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

Magnitude of $v-u$ graph



* Principles of Reversibility :—

> The property of the light which is incident normal to the reflecting surface after reflection it retraces its path is called Principle of Reversibility.

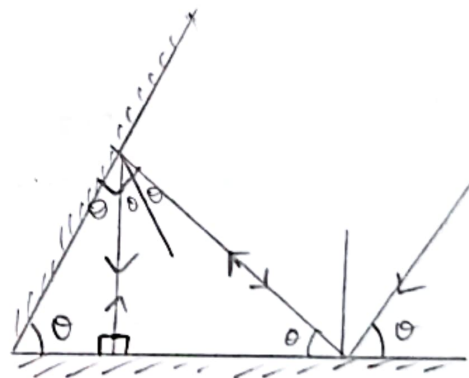


$$2\theta + 90^\circ = 180^\circ$$

$$2\theta = 180^\circ - 90^\circ$$

$$2\theta = 90^\circ$$

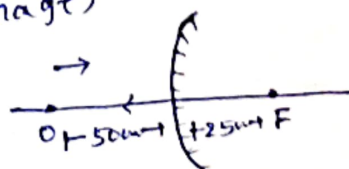
$$\boxed{\theta = 45^\circ}$$



* (Q) from mains-1 :—

(12) (Virtual image).

$$3) 50 \text{ (10.6)}$$



$$R = 50 \text{ cm}$$

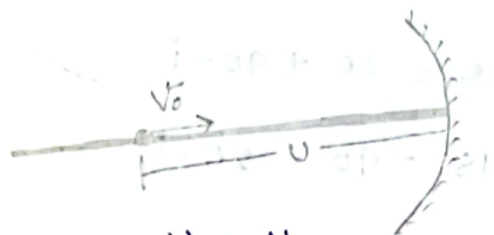
$$f = 25 \text{ cm}$$

$$v = \frac{u f}{u - f} = \frac{-50 \times 25}{-50 - 25} = \frac{-1500}{-75} = +20 \text{ cm}$$

* Mains-1 *

(13) The speed of the obj. V_o . obj distance U . The Speed of the image is :-

(A) Image distance $(V) = \frac{Uf}{U-f}$



$$U = -U$$

$$R = 2f$$

$$f = -R/2$$

$$V = \frac{Uf}{U-f}$$

$$V = \frac{(-U)(-R/2)}{-U + R/2}$$

$$V = \frac{RU/2}{\frac{-2U+R}{2}}$$

$$V = \frac{RU}{R-2U}$$

$$V_i = -\left(\frac{V}{U}\right)^2 V_o$$

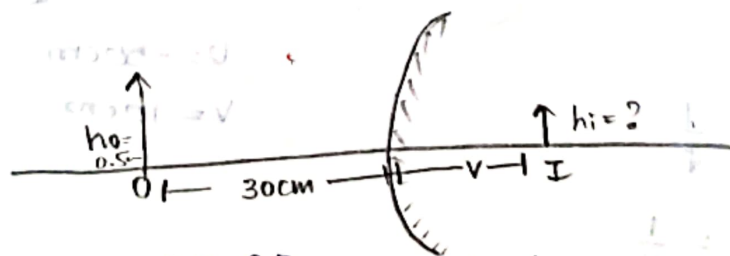
$$V_i = -\left(\frac{R}{R-2U}\right)^2 V_o$$

$$V_i = -\left(\frac{R}{2U-R}\right)^2 V_o$$

$$V_i = \left(\frac{R}{2U-R}\right)^2 V_o$$

$$\frac{V}{U} = \frac{R}{R-2U}$$

(11) A 0.5 cm height object is placed at 30 cm from the convex mirror of focal length 20 cm. The position & size of the image.



$$U = -30 \text{ cm}$$

$$f = +20 \text{ cm}$$

$$V = +12 \text{ cm}$$

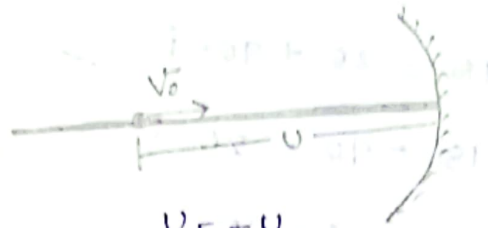
$$V = \frac{Uf}{U-f} = \frac{-30 \times 20}{-30 - 20} = \frac{-600}{-50} = 12 \text{ cm}$$

$$m = -\frac{V}{U}$$

$$\frac{h_i}{h_o} = -\frac{V}{U} \Rightarrow \frac{h_i}{0.5} = \frac{-12}{-30}$$

(13) The speed of the obj. v_o . obj distance U . The speed of the image is :-

(A) Image distance $(v) = \frac{uf}{u-f}$



$$U = -U$$

$$R = 2f$$

$$f = -R/2$$

$$v = \frac{uf}{u-f}$$

$$v = \frac{(-U)(-R/2)}{-U + R/2}$$

$$v = \frac{RU/2}{\frac{-2U + R}{2}}$$

$$v = \frac{RU}{R-2U}$$

$$v_i = -\left(\frac{v}{u}\right)^2 v_o$$

$$v_i = -\left(\frac{R}{R-2U}\right)^2 v_o$$

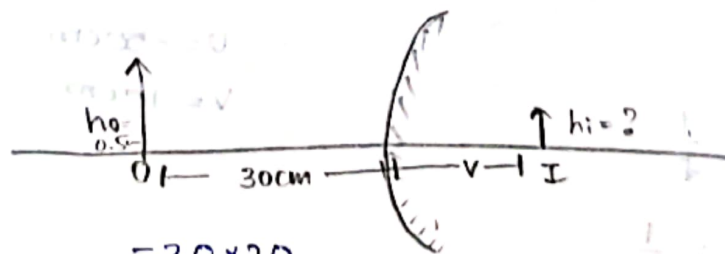
$$(14) v_i = -\left(\frac{R}{2U-R}\right)^2 v_o$$

$$v_i = \left(\frac{R}{2U-R}\right)^2 v_o$$

←

$$\frac{v}{u} = \frac{R}{R-2U}$$

(11) A 0.5 cm height object is placed at 30 cm from the convex mirror of focal length 20 cm . The position & size of the image.



$$U = -30 \text{ cm}$$

$$f = +20 \text{ cm}$$

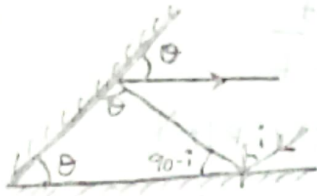
$$v = +12 \text{ cm}$$

$$v = \frac{uf}{u-f} = \frac{-30 \times 20}{-30 - 20} = \frac{-600}{-50} = 12 \text{ cm}$$

$$m = -\frac{v}{u}$$

$$\frac{h_i}{h_o} = -\frac{v}{u} \Rightarrow \frac{h_i}{0.5} = \frac{-12}{-30}$$

- ④ Two plane mirrors makes an angle θ . The light incident at an angle i . The light ray reflected from this mirror falls on second mirror from where its reflected parallel to the plane mirror. The value of i is 2



$$180 = 2\theta + 90 - i$$

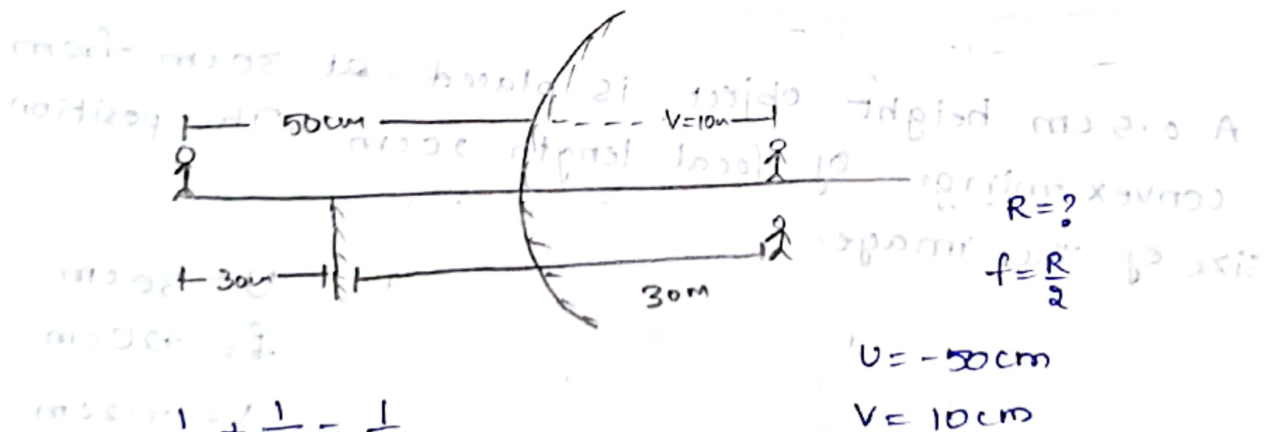
$$180 - 90 = 2\theta - i$$

$$2\theta - i = 90$$

$$-i = 90 - 2\theta$$

$$i = 2\theta - 90$$

- * ⑤ An object is placed at a distance 50 cm from a convex mirror. A plane mirror is covered half of the convex mirror. Object distance 30 cm then there the two images are coincide. The radius of curvature.



$$\frac{1}{V} + \frac{1}{U} = \frac{1}{f}$$

$$\frac{1}{10} + \frac{1}{50} = \frac{1}{f}$$

$$\frac{1}{10} - \frac{1}{50} = \frac{2}{R} \Rightarrow \frac{5-1}{50} = \frac{2}{R}$$

$$\Rightarrow \frac{4}{50} = \frac{2}{R}$$

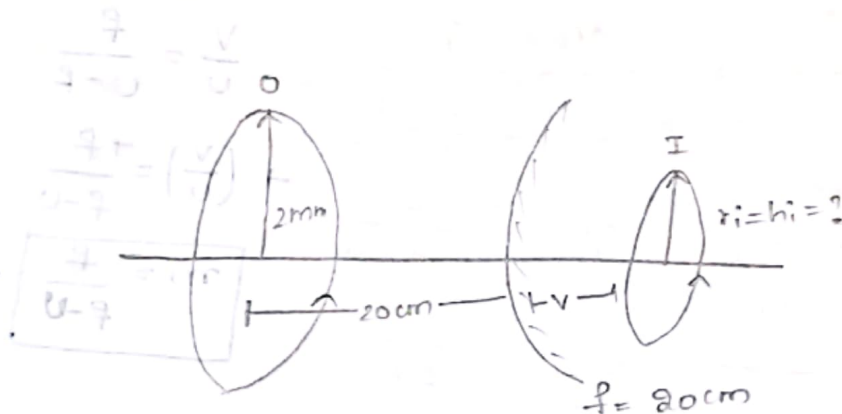
$$\Rightarrow \frac{1}{25} = \frac{1}{R} \Rightarrow R = 25 \text{ cm}$$

$$V_{IM} = -44\hat{i} + 24\hat{j}$$

②

08/04/2024: (Mon) :-

> (Q) A small particle revolving in circular motion with radius 2mm. A convex mirror of focal length 20cm. Find linear velocity of the particle and position of the image. (The time period of the particle is 2sec).



$$u = -20 \text{ cm}$$

$$f = +20 \text{ cm}$$

$$v = \frac{uf}{u-f}$$

$$v = \frac{-20 \times 20}{-20 - 20}$$

$$v = \frac{+400}{+40}$$

$$v = +10 \text{ cm}$$

$$\frac{h_i}{h_o} = -\frac{v}{u}$$

$$\frac{h_i}{2 \text{ mm}} = -\left(\frac{10}{-20}\right)$$

$$\frac{h_i}{2 \text{ mm}} = \frac{1}{2}$$

$$h_i = 1 \text{ mm}$$

$$\text{Time period} = 2 \text{ sec.}$$

$$\text{Velocity (v)} = h_i \omega$$

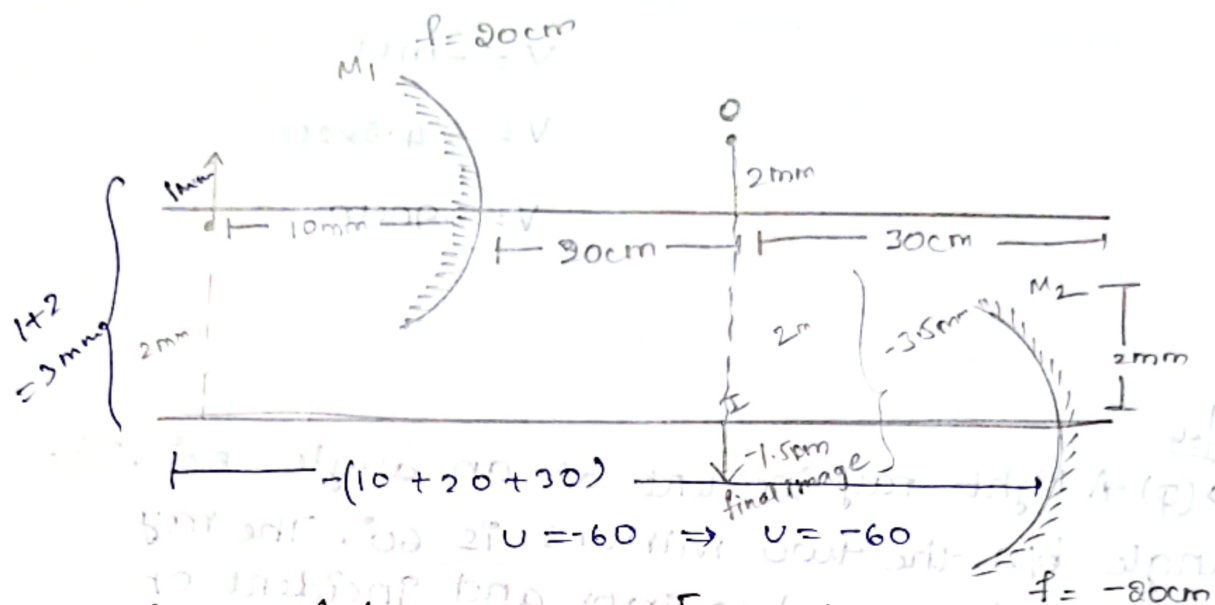
$$v_i = h_i \cdot \frac{2\pi}{T}$$

$$v_i = \frac{1 \times 2\pi}{2} \times 10^{-3} \text{ m/s}$$

$$v_i = 3.141 \times 10^{-3} \text{ m/s}$$

↳ π value.

> (Q) Two Spherical mirrors each of focal length 20cm



For mirror M1:

$$U = -20 \text{ cm}$$

$$f = +20 \text{ cm}$$

$$V = \frac{Uf}{U-f}$$

$$V = \frac{-20 \times 20}{-20 - 20}$$

$$V = \frac{+400}{+40}$$

$$V = +10 \text{ cm}$$

$$\frac{h_i}{h_o} = -\frac{V}{U}$$

$$\frac{h_i}{2 \text{ mm}} = +\frac{10}{+20}$$

$$h_i = 1 \text{ mm}$$

For mirror M2:

$$U = -60 \text{ cm}$$

$$f = -20 \text{ cm}$$

$$V = \frac{Uf}{U-f}$$

$$V = \frac{-60 \times -20}{-60 + 20} = \frac{-30 \times -20}{-40}$$

$$V = -30 \text{ cm}$$

$$\frac{h_i}{h_o} = -\frac{V}{U}$$

$$(1+2 \text{ mm}) \frac{h_i}{3 \text{ mm}} = -\left(\frac{+30}{+60}\right)$$

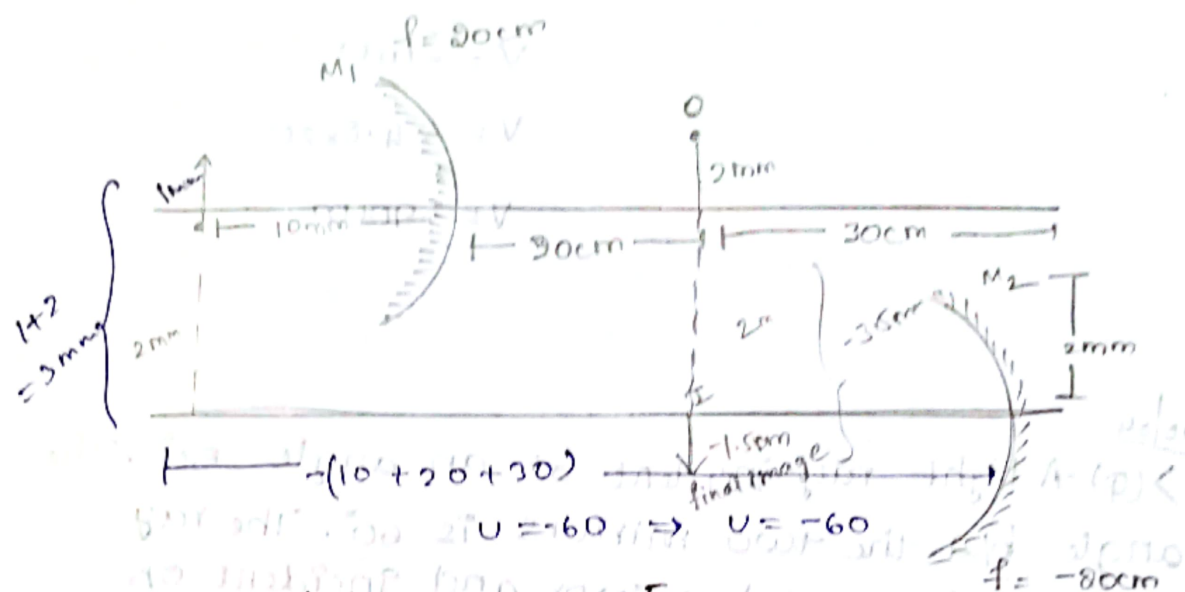
$$\frac{h_i}{3 \text{ mm}} = -\frac{1}{2}$$

$$h_i = -\frac{3}{2}$$

$$h_i = -1.5 \text{ mm}$$

The Coordinates of final image = $(20 \text{ cm}, -3.5 \text{ mm})$

Q) Two spherical mirrors, each of focal length 20cm



For mirror M_1 :

$$U = -20 \text{ cm}$$

$$f = +20 \text{ cm}$$

$$V = \frac{Uf}{U-f}$$

$$V = \frac{-20 \times 20}{-20 - 20}$$

$$V = \frac{+400}{+40}$$

$$V = +10 \text{ cm}$$

$$\frac{h_i}{h_o} = -\frac{V}{U}$$

$$\frac{h_i}{3 \text{ mm}} = +\frac{10}{20}$$

$$h_i = 1.5 \text{ mm}$$

For mirror M_2 :

$$U = -60 \text{ cm}$$

$$f = -20 \text{ cm}$$

$$V = \frac{Uf}{U-f}$$

$$V = \frac{-60 \times -20}{-60 + 20} = \frac{-60 \times -20}{-40}$$

$$V = -30 \text{ cm}$$

$$\frac{h_i}{h_o} = -\frac{V}{U}$$

$$(1+2 \text{ mm}) \frac{h_i}{3 \text{ mm}} = -\left(\frac{-30}{-60}\right)$$

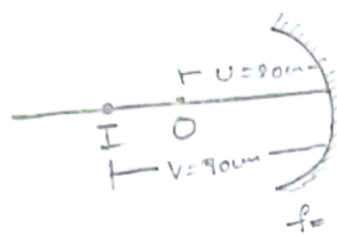
$$\frac{h_i}{3 \text{ mm}} = -\frac{1}{2}$$

$$h_i = -1.5 \text{ mm}$$

$$h_i = -1.5 \text{ mm}$$

The coordinates of final image = (20cm, -3.5mm)

10/04
> (Q) A real image formed by concave mirror is 4.5 times size of object. If mirror is 20cm from the object the focal length is.



$$m = -\frac{V}{U}$$

$$V = -mU$$

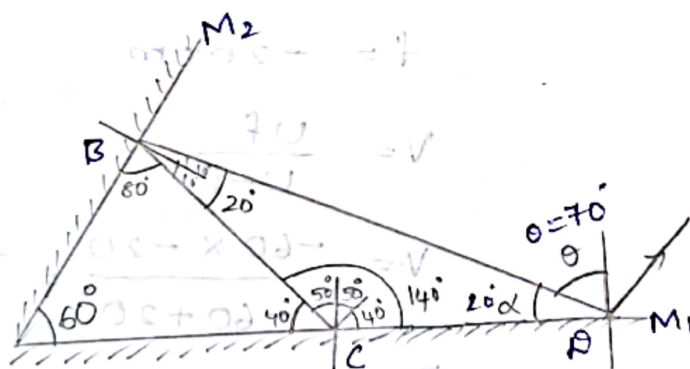
$$V = -4.5 \times 20$$

$$V = -90\text{cm}$$

10/04

> (Q) A light ray incident at an angle 50° . The angle b/w the two mirrors is 60° . The ray touches the second mirror and incident on first mirror. It makes angle of incidence is

(A)



$$\triangle BCD : \alpha + 20^\circ + 140^\circ = 180^\circ$$

$$\alpha + 160^\circ = 180^\circ$$

$$\alpha = 180^\circ - 160^\circ$$

$$\boxed{\alpha = 20^\circ}$$

$$\alpha + \theta = 90^\circ$$

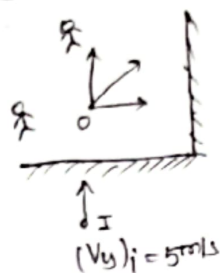
$$20^\circ + \theta = 90^\circ$$

$$\boxed{\theta = 70^\circ}$$

Main-2.

- ④ Two adjacent walls arranged with mirror, a man stand & observe the image of the insect is moving horizontally with speed 3 m/s. Another image with speed 5 m/s vertically. What is the actual speed of the insect.

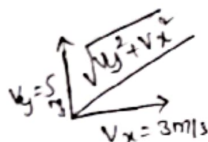
①



$$V_I$$

$$(V_I)_x = 3 \text{ m/s}$$

$$(V_I)_y = 5 \text{ m/s}$$



$$V_I = \sqrt{(3)^2 + (5)^2}$$

$$V_I = \sqrt{9 + 25}$$

$$V_I = \sqrt{34}$$

②

- ⑦ A concave mirror is used to focus image of a flower on wall 120 cm from the flower. Lateral magnification is 16. The distance of flower.

①

$$\frac{h_i}{h_o} = -\frac{v}{u} = m$$

$$\frac{U+120}{U} = 16$$

$$U+120 = 16U$$

$$120 = 15U$$

$$U = \frac{120}{15} = 8$$

$$U = 8 \text{ cm}$$

Advanced-1.

- ② A beautiful girl with two normal eyes to see full width of her face by a plane mirror. The eye to eye and ear to ear distances of her face at 4 inch and 6 inch respectively. The minimum width of the required mirror is

Mains level:

$$\text{min size of mirror (x)} = \frac{d_{\text{ears}} - d_{\text{eyes}}}{2}$$

$$x = \frac{6-4}{2} = \frac{2}{2} = 1 \text{ inch}$$

Adv level:

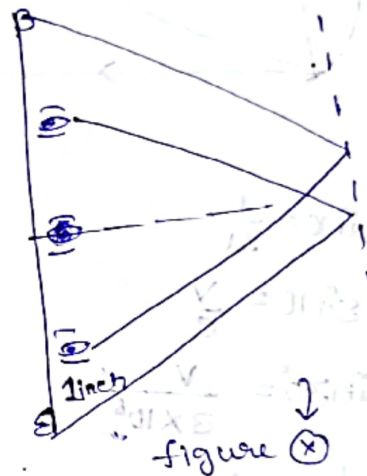
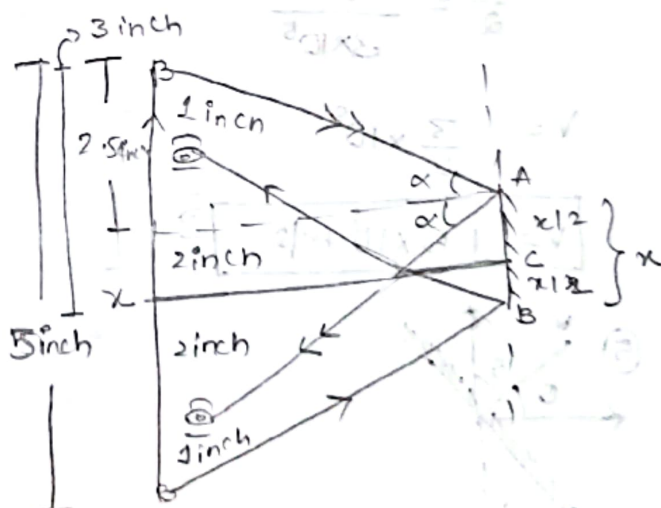


figure ⑩

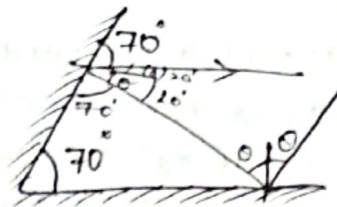


From fig $AC = 3 - 2.5$
 $AC = 0.5$

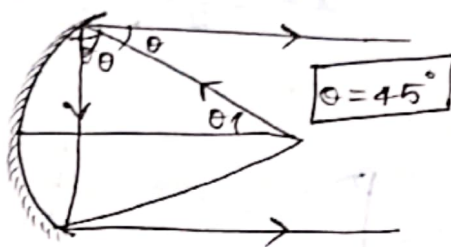
Similarly $CB = 0.5$

$$AB = AC + CB = 0.5 + 0.5 = 1 \text{ inch}$$

10) The circular boundary of the concave mirror subtends a cone of half angle θ at its centre of curvature. The min. value of θ for which ray incident on this mirror parallel to the principal axis suffers more than one reflection is:-



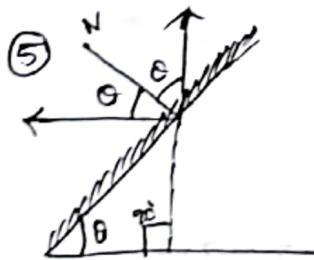
(A)



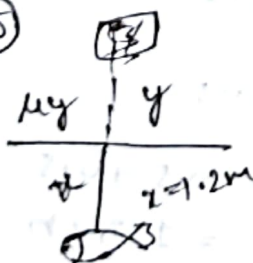
$$\begin{aligned} \text{17) } \sin c &= \frac{1}{u} \\ \sin c &= \frac{v}{c} \\ \sin 30^\circ &= \frac{v}{3 \times 10^8} \\ \frac{1}{2} &= \frac{v}{3 \times 10^8} \end{aligned}$$

$$v = \frac{3}{2} \times 10^8$$

$$v = 1.5 \times 10^8 \text{ m/s}$$



25)



$$h = \mu y + z$$

$$h = \frac{4}{3} \times \frac{1.2}{3} + 1.2$$

$$h = 4.8 + 1.2$$

$$h = 6\text{m}$$

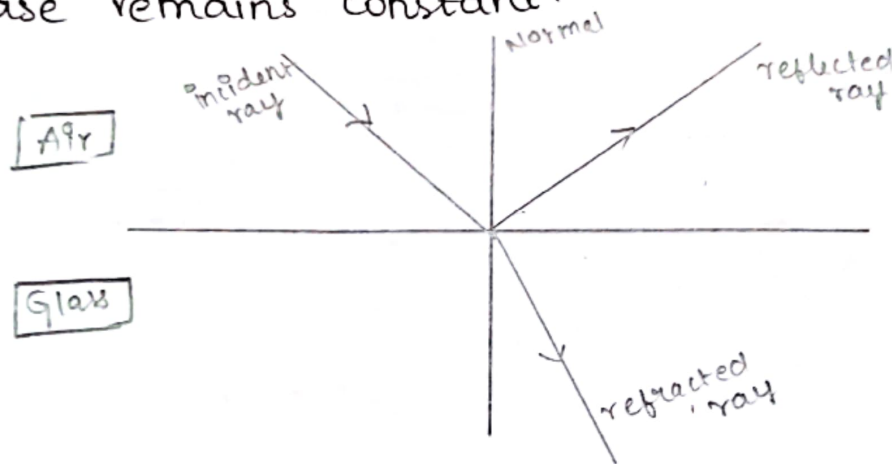
08/04/2024 :- (Mon) :-

-° REFRACTION OF LIGHT :-

* Introduction :-

> When light ray travel from one medium to another medium a part of light is reflected and remaining part of light travel from one medium to another medium such ray is called Refracted ray. ✓

> * When light ray travel from one medium to another medium wavelength (λ) , velocity changes, direction changes but frequency (ν) & phase remains constant.



* Refractive Index of air = 1.003

* Refractive Index of vacuum = 1
Both taken as 1.

> In electromagnetic spectrum all colours has same speed in vacuum ($c = 3 \times 10^8 \text{ m/s}$). But when light travel in medium different colours has different velocities based on optical density (or) refractive index (μ).

* Absolute refractive index (ARI) :- (2m) (I.p.e)

> Yellow colour is more sensitive colour (more intensity compared to all colours)

Graph of yellow colour :-



I $\rightarrow$ intensity.

A.P.T :- (μ)

> Def:- The ratio of speed of light in vacuum (air) to speed of light in medium is called Absolute Refractive Index (μ).

> It is represented by μ .

Formula:-

$$\mu = \frac{\text{Speed of light in vacuum (c)}}{\text{Speed of light in medium (v)}}$$

$$\mu = \frac{c}{v}$$

> It is a scalar quantity.

> It has no units & no dimensional formula.

> It depends on nature of the medium.

* Note:-

* When temperature changes refractive index changes &

* When wavelength changes refractive index of the medium changes.

$$\mu \propto \frac{1}{\lambda}$$

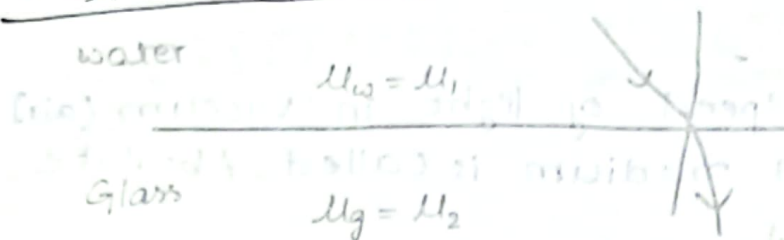
* Relative refractive index (μ_r):-

> The ratio of speed of light in first medium to speed of light in second medium is called Relative refractive index.

$$\mu_2 \text{ or } {}^1\mu_2 = \frac{\text{Speed of light in medium } \textcircled{1}}{\text{Speed of light in medium } \textcircled{2}}$$

$$\frac{\mu_2}{\mu_1} = \frac{v_1}{v_2}$$

R.K. Sir Trick / concept:-



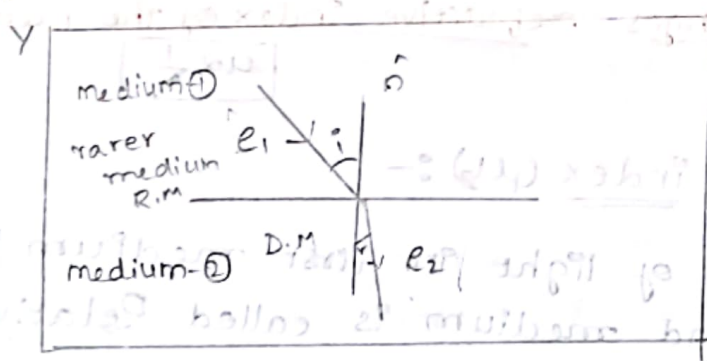
$$\frac{\mu_2}{\mu_1} = \mu_2 = \mu_2 = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{d_1}{d_2} = \frac{t_2}{t_1}$$

* Note:- When light ray travel from one medium to another medium the relative refractive index defined as refractive index of second medium with respect to first medium's refractive index.

* Law of Refraction:-

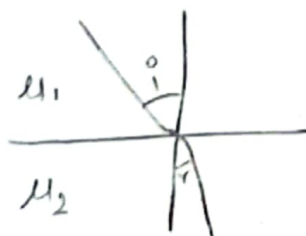
① First law:-

According to law of refraction, incident ray, refracted ray & normal are in same plane ✓



② second law:-

When light ray travel from one medium to another medium, the product of sine angle & refractive index of the same medium remains constant.



$$\mu \sin i = \text{constant}$$

$$\mu_1 \sin i_1 = \mu_2 \sin r_1 = \text{constant}$$

* Snell's law :-

> According to Snell's law; the ratio of sine angle of incidence to sine angle of refraction remains constant.

$$\frac{\sin i}{\sin r} = \text{constant}$$

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} = {}^1\mu_2 \text{ or } {}^1\mu_2$$

(OR)

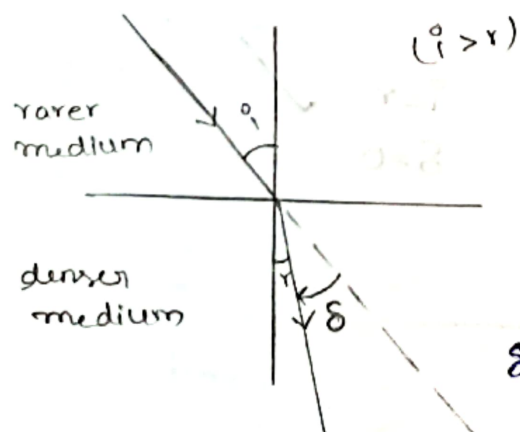
$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} \quad \checkmark$$

* Angle of Deviation in Refraction :-

Case-I :-

> When light ray travel from rarer medium to denser medium with angle of incidence i & angle of refraction r . The angle of deviation is

* When light ray travel from rarer medium to denser medium angle of incidence (i) > angle of refraction (r)



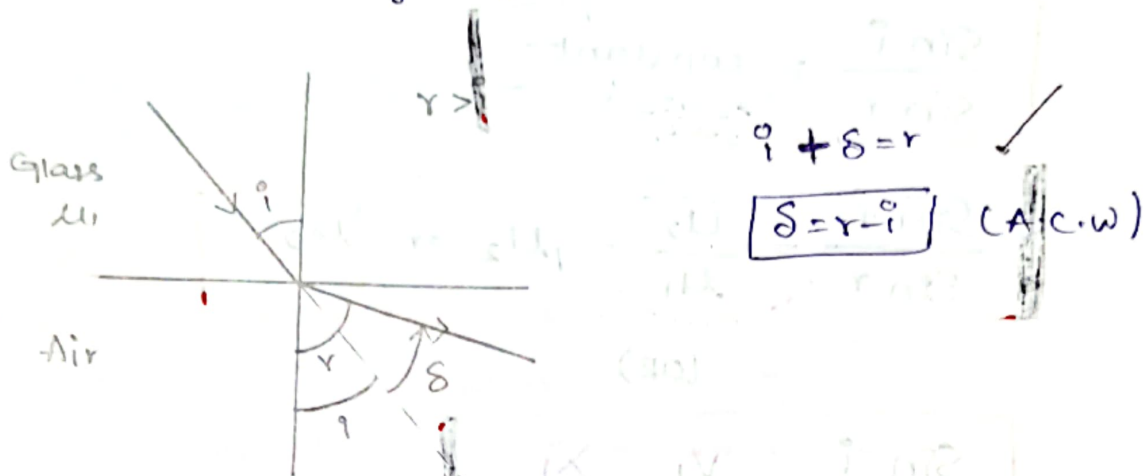
$$i = r + \delta \quad \checkmark$$

$$* \delta = i - r \text{ (C.W)} *$$

δ (C.W)

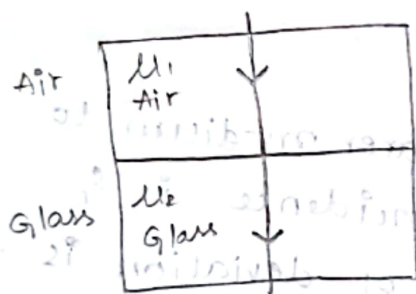
Case-(2):-

When light ray travel from denser medium to rarer medium the light ray bend away from the normal. The angle of deviation is



Case-(3):-

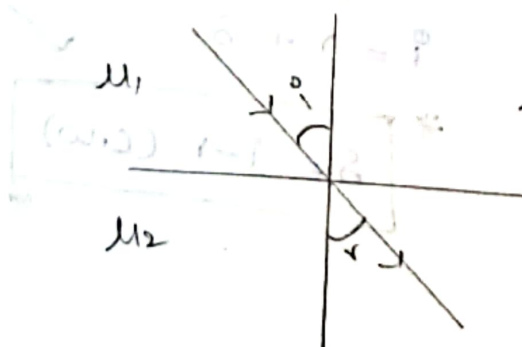
When light ray incident normal to the refracting surface the angle of deviation is



$$\begin{aligned} i &= 0 \\ r &= 0 \\ \delta &= 0 \end{aligned}$$

Case-(4):-

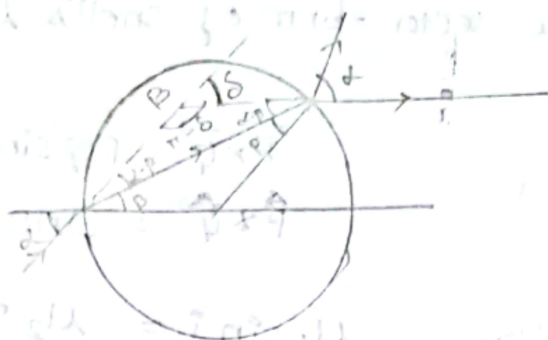
Two mediums having same refractive index the angle of deviation is



$$\mu_1 = \mu_2$$

$$\begin{aligned} i &= r \\ \delta &= 0 \end{aligned}$$

✓ >(Q) A glass sphere of refractive index 1.5. A light ray passes through it as shown in figure. Find angle of deviation.



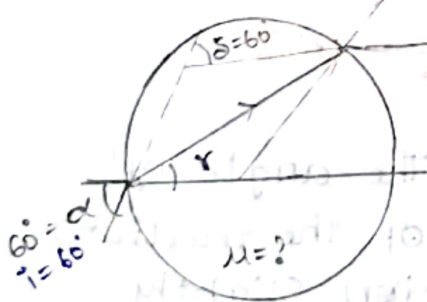
From the triangle ABC;

$$\alpha - \beta + \alpha - \beta + \pi - \delta = 2\pi$$

$$2\alpha - 2\beta = \delta \Rightarrow \boxed{\delta = 2(\alpha - \beta)} \quad \text{C.W.D.}$$

with the normal

✓ >(Q) A light ray incident at angle 60° . The emergent ray parallel to the normal. The refractive index of the sphere is.



$$\delta = 60^\circ; \quad \alpha = 60^\circ$$

$$\delta = 2(\alpha - \beta)$$

$$60^\circ = 2(60^\circ - \beta)$$

$$60^\circ = 120^\circ - 2\beta$$

$$-2\beta = 60^\circ - 120^\circ$$

$$2\beta = 60^\circ$$

$$\boxed{\beta = 30^\circ = r}$$

$$\mu_1 \sin i = \mu_2 \sin r$$

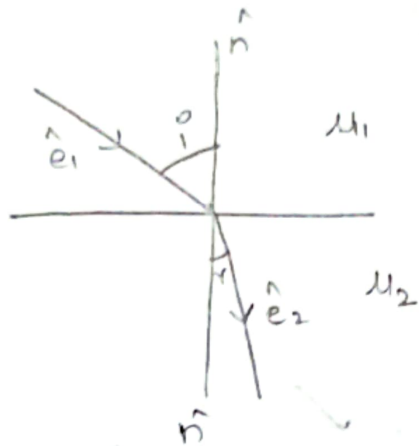
$$1 \times \sin 60^\circ = \mu \sin 30^\circ$$

$$\frac{\sqrt{3}}{2} = \mu \times \frac{1}{2}$$

$$\boxed{\mu = \sqrt{3} \text{ (or) } 1.732}$$

* Vector form of Snell's law :-

> A light ray incident at an angle i , it refracted at an angle r the refractive index of the medium μ_1 and μ_2 . The vector form of Snell's law is.



$$\vec{P} \times \vec{Q} = PQ \sin \theta$$

$$\hat{P} \times \hat{Q} = \sin \theta$$

$$\mu_1 \sin i = \mu_2 \sin r$$

$$\sin i = \hat{e}_1 \times \hat{n}$$

$$\sin r = \hat{e}_2 \times \hat{n}$$

$$\boxed{\mu_1 (\hat{e}_1 \times \hat{n}) = \mu_2 (\hat{e}_2 \times \hat{n})}$$

* Note :-

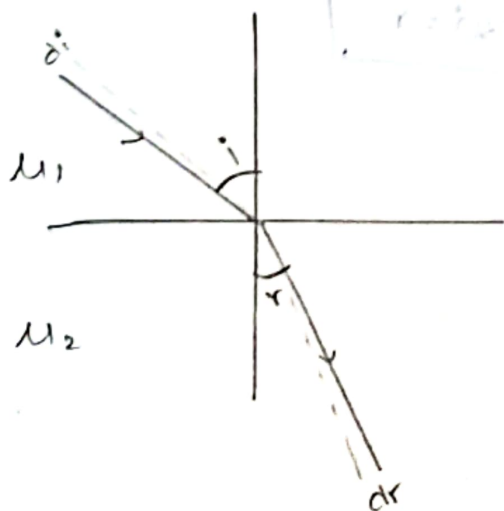
Refractive index of glass = $\frac{3}{2} = 1.5$

Refractive index of air = $1.003 \approx 1$

Refractive index of water = $\frac{4}{3} = 1.33$

Concept :-

> (Q) The angle of incidence i . The angle of refraction r . The refractive index of the medium μ_1 & μ_2 . If angle of refraction slightly change (dr). Find change in angle of refraction



Snell's law :-

$$\mu_1 \sin i = \mu_2 \sin r$$

$$\mu_1 \cos i \, di = \mu_2 \cos r \, dr$$

$$\boxed{dr = \left(\frac{\mu_1}{\mu_2} \right) \left(\frac{\cos i}{\cos r} \right) di}$$

10/04/2024 (Wed) :-

JEE-Mains

> (Q) The refractive index of the glass w.r. to water $\frac{9}{8}$. The velocity of the light in glass $2 \times 10^8 \text{ m/s}$ and wavelength of the light $4000 \text{ \AA}$. Find Velocity of light in water & wavelength of the light in water.

(A) $\frac{\mu_g}{\mu_w} = \frac{9}{8}$

$$\frac{\mu_g}{\mu_w} = \frac{\lambda_w}{\lambda_g}$$

$$\frac{9}{8} = \frac{\lambda_w}{\frac{4000}{500}}$$

$$\lambda_w = 500 \times 9$$

$$\lambda_w = 4500 \text{ \AA}$$

$$\lambda_g = 4000 \text{ \AA}; \lambda_w = ?$$

$$V_g = 2 \times 10^8 \text{ m/s}; V_w = ?$$

$$\frac{\mu_g}{\mu_w} = \frac{V_w}{V_g}$$

$$\frac{9}{8} = \frac{V_w}{2 \times 10^8}$$

$$V_w = 2.25 \times 10^8 \text{ m/s}$$

* The speed of light in vacuum is c . The Permittivity is ϵ_0 . The permeability is μ_0 . The Speed of light in medium.

$$\text{The speed of light in vacuum } (c) = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

The speed of light in medium

$$\hookrightarrow (V_m) = \frac{1}{\sqrt{\mu_m \epsilon_m}} = 3 \times 10^8$$

$$\text{Relative permittivity} = \frac{\mu_m}{\mu_0} \frac{\epsilon_m}{\epsilon_0}$$

$$\text{Relative permeability} = \frac{\mu_m}{\mu_0}$$

Dividing ① & ②

$$\frac{x}{AC} \times \frac{AC}{t} = \frac{\sin \delta}{\cos r}$$

$$x = t \frac{\sin \delta}{\cos r}$$

used $\theta > 10^\circ$

$$\text{lateral shift } (x) = \frac{t \sin(i-r)}{\cos(r)}$$

Board models

→ Main model : →

For small angle of incidence $\sin(i-r) \approx i-r$
 $\cos r \approx 1$

$$x = \frac{t(i-r)}{1}$$

WKT,

$$x = \frac{t \sin(i-r)}{\cos r} = \frac{t(i-r)}{1}$$

↓

$$x = t i \left(1 - \frac{r}{i}\right)$$

According Snell's law

$$\mu_1 \sin i = \mu_2 \sin r$$

for small angle

$$\mu_1 i = \mu_2 r$$

$$\frac{r}{i} = \frac{\mu_1}{\mu_2}$$

$$\text{lateral shift } (x) = t i \left(1 - \frac{\mu_1}{\mu_2}\right)$$



lateral shift in this lateral

> (Q) A glass slab of thickness is 0.1 cm. The angle of deviation 60° & angle of refraction 60° . The lateral shift is.

(A) KIKT,

$$x = \frac{t \sin(i-r)}{\cos r}$$

$$x = \frac{t \sin(60^\circ)}{\cos 60^\circ}$$

$$x = \frac{10^{-3} \times \sqrt{3}/2}{1/2} \text{ m}$$

$$x = 1.732 \times 10^{-3} \text{ m}$$

$$x = 1.732 \text{ mm}$$

Given,

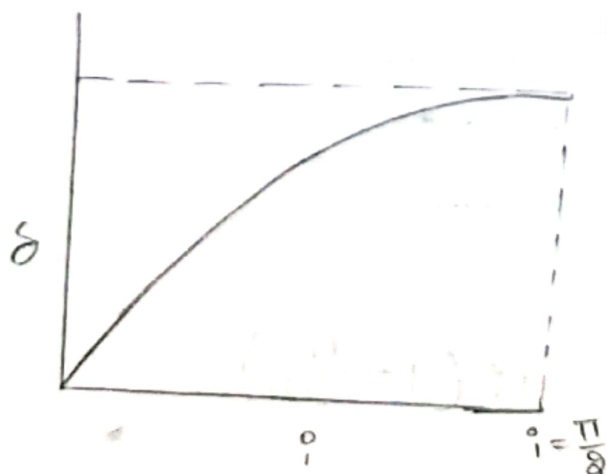
$$t = 0.1 \text{ cm} = 10^{-3} \text{ m}$$

$$\delta = 60^\circ$$

$$r = 60^\circ$$

$$\delta = i - r$$

> (Q) A graph drawn b/w angle of deviation on Y-axis and angle of incidence on X-axis. The condition for maximum lateral displacement or lateral shift.



$$x = \frac{t \sin(i-r)}{\cos r}$$

$$i = \frac{\pi}{2}; r = c$$

$$x = \frac{t \sin(\frac{\pi}{2} - c)}{\cos c}$$

$$x = t \frac{\cos c}{\cos c}$$

$$x_{\max.} = t$$

lateral shift or lateral displacement

* Optical path *

Definition:- The distance travelled by the light in vacuum for a given time is called optical path.

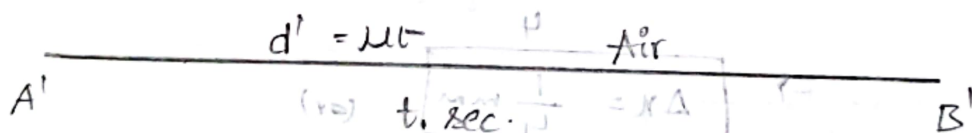
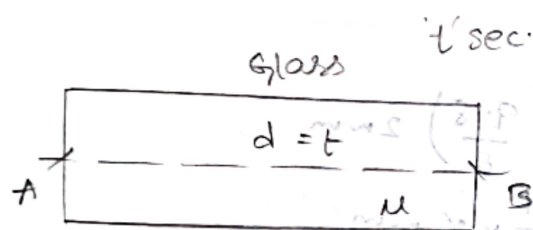
(OR)

The product of refractive index of the medium and distance travelled by the light in same medium is called optical path of light.

$$\text{Optical path } (d') = \mu d$$

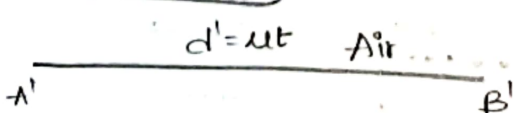
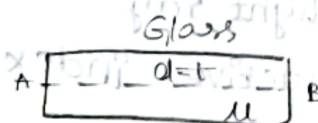
Explanation:-

> Let the refractive index of the medium is (μ) .
The distance travelled by the light is 'd' in 't' seconds. The optical path of light in same time is



$$\text{Optical path of light } d' = \mu d$$

> The refractive index of the medium is ' μ '. The thickness of the glass slab ' t '. The optical path difference is :-



optical difference formula:

$$\Delta x = d' - d$$

$$= \mu t - t$$

$$= t(\mu - 1)$$

So,

$$\Delta x = t(\mu - 1)$$

* Optical path *

Definition:- The distance travelled by the light in vacuum for a given time is called optical path.

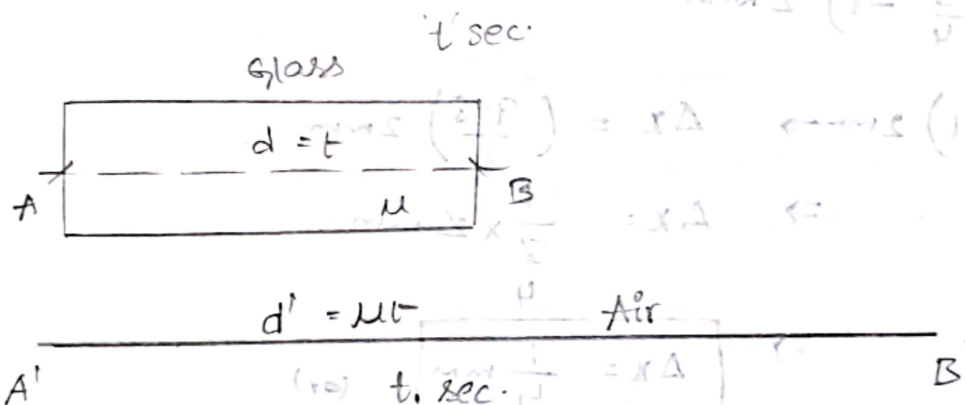
(OR)

The product of refractive index of the medium and distance travelled by the light in same medium is called optical path of light.

$$\text{Optical path } (d') = \mu d$$

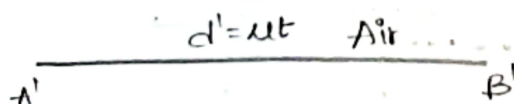
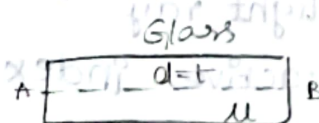
Explanation :-

> Let the refractive index of the medium is (μ) .
The distance travelled by the light is 'd' in 't' seconds. The optical path of light in same time is



$$\text{Optical path of light } d' = \mu d$$

> The refractive index of the medium is ' μ ', the thickness of the glass slab ' t ', the optical path difference is :-



Optical difference formula:-

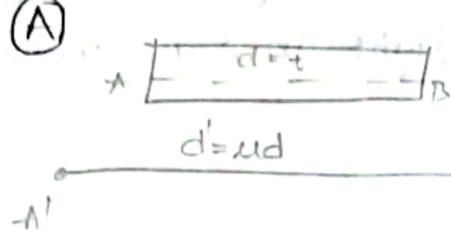
$$\begin{aligned} \Delta x &= d' - d \\ &= \mu t - t \\ &= t(\mu - 1) \end{aligned}$$

So,

$$\Delta x = t(\mu - 1)$$

> (Q) The refract light ray travel from water to glass of refractive index $\frac{4}{3}$ and $\frac{3}{2}$ respectively. It has same thickness 2mm the optical path difference is?

(A)



VVI

$$\Delta x = \left(\frac{\mu_g}{\mu_w} - 1 \right) t$$

$$\Delta x = \left(\frac{\frac{3}{2}}{\frac{4}{3}} - 1 \right) 2 \text{ mm}$$

$$\Delta x = \left(\frac{3}{2} \times \frac{3}{4} - 1 \right) 2 \text{ mm}$$

$$\Delta x = \left(\frac{9}{8} - 1 \right) 2 \text{ mm} \Rightarrow \Delta x = \left(\frac{9-8}{8} \right) 2 \text{ mm}$$

$$\Rightarrow \Delta x = \frac{1}{8} \times 2 \text{ mm}$$

$$\Rightarrow \Delta x = \frac{1}{4} \text{ mm} \quad (\text{or})$$

$$\Delta x = 0.25 \text{ mm} \quad (\text{or})$$

$$\Delta x = 0.00025 \text{ m}$$

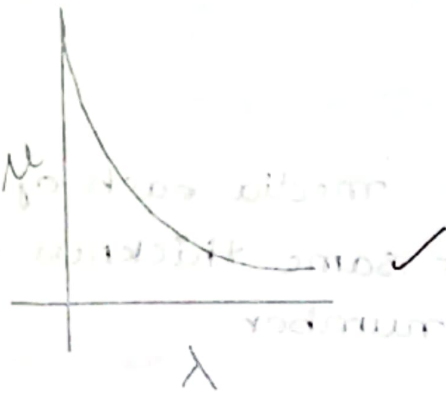
* Cauchy's law *

> According to Cauchy's law; when light ray passes through the medium the refractive index represents

$$\mu = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \dots$$

where :- $A, B, C \rightarrow \text{constants}$.

> A graph drawn b/w refractive index on y-axis & wavelength on x-axis. The nature of the graph represents as show in figure.



* WAVE LENGTH *

* WAVE NUMBER ($\bar{\nu}$) *

> The reciprocal of the wavelength of the light in a given medium is called wave number

(OR)
The ratio of distance travel by the light to wavelength of the light in same medium is called wave number ($\bar{\nu}$)

$$\bar{\nu} = n \propto \frac{1}{\lambda_m}$$

$$\bar{\nu} = n = \frac{d}{\lambda_m}$$

$$\text{Wave length } (\lambda_m) = \frac{\lambda_0}{\mu}$$

$$\bar{\nu} = n = \frac{\mu d}{\lambda_0}$$

$$\bar{\nu} = \frac{\text{optical path}}{\lambda_0}$$

($\because \mu d = \text{optical path}$)

$\lambda_0 \rightarrow$ wavelength in air

* Note :-

It has no units and no dimensional formula.
It is a scalar quantity. ✓

Jee-Main :-

> (Q) Two different media each of refractive index μ_g & μ_w but same thickness. Find difference in wave number

wave number $\bar{\nu}_1 = n_1 = \frac{\mu_g d}{\lambda_0}$

wave number $\bar{\nu}_2 = n_2 = \frac{\mu_w d}{\lambda_0}$

$$n_1 - n_2 = \Delta \bar{\nu} = \frac{\mu_g d}{\lambda_0} - \frac{\mu_w d}{\lambda_0}$$

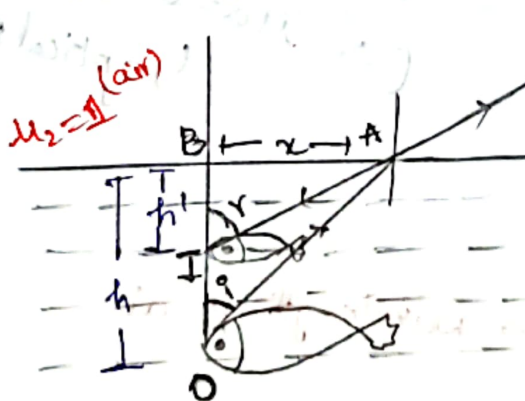
wave number difference

$$\Delta \bar{\nu} = \frac{d}{\lambda_0} (\mu_g - \mu_w)$$
 ✓

*** one @ pacca :-

*** Apparent Depth ***

Introduction: A fish inside the water at real depth 'h'. The refractive index is μ . A bird flying in air the apparent depth of the fish is



From the ΔOAB

$$\sin i = \frac{AB}{OB} = \frac{x}{h}$$

for small angle

$$\tan i = \sin i = i$$

for small angle

$$\sin i = \frac{x}{h} \rightarrow (1)$$

From $\triangle ABI$

$$\tan r = \frac{AB}{BI} = \frac{x}{h'}$$

for small angle $\tan r = \sin r = r$

$$\sin r = \frac{x}{h'} \rightarrow (2)$$

According to Snell's law:-

$$\mu_1 \sin i = \mu_2 \sin r$$

$$\mu_1 \times \frac{x}{h} = \mu_2 \times \frac{x}{h'}$$

$$\text{Apparent depth } (h') = \left(\frac{\mu_2}{\mu_1} \right) h \quad *$$

(OR)

$$\mu_2 = 1 \quad \text{and} \quad \mu_1 = \mu$$

$$\text{Apparent depth } h' = \frac{h}{\mu} \quad * \checkmark$$

* Apparent Shift *

$$\Delta x = h - h'$$

$$\Delta x = h - \frac{h}{\mu}$$

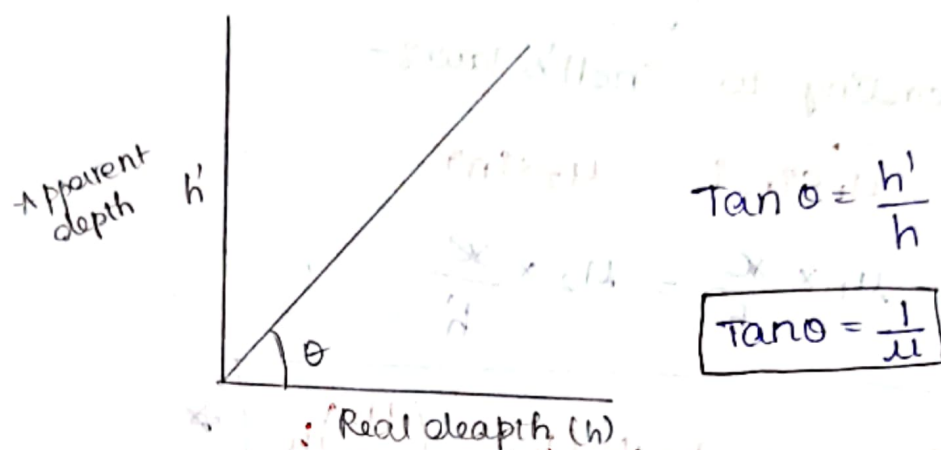
$$\Delta x = h \left(1 - \frac{1}{\mu} \right) \quad * \checkmark$$

* Graph:-

> A graph drawn b/w apperent height on y-axis (h'). The real height (or) real depth (h) on x-axis.

It represents a straight line passes through the origin. We know apperent depth $h' = \frac{h}{\mu}$

$$h' \propto h$$



13/04/2024 (Sat):-

* Note:- The position of the observer doesnot depends on apperent depth & apperent shift.

> The total apperant depth seen by the bird is:-

The total apperant depth (h) = $y + x'$

$$h = y + \frac{x}{\mu}$$

Depth
↓
Divide
 μ'
height
↓
multiply
 μ'

> The total apperent cleapth (h) = $y + \frac{x}{\mu}$

Differentiate w.r. to t

[B]

$$\frac{dh}{dt} = \frac{dy}{dt} + \frac{1}{\mu} \cdot \frac{dx}{dt}$$

$$V_{BF} = V_B + \frac{1}{\mu} \cdot V_F$$

$$* \quad V_{BF} = V_B + \frac{V_F}{\mu}$$

> (Q) The velocity of the fish 3 cm/s. The velocity of the bird 6 cm/s moves towards surface of the water and seen by the fish with velocity 9 cm/s. The refractive index of the medium (water).

(A) $V_{BF} = V_B + \frac{V_F}{\mu}$

$V_{BF} = 9$
 $V_B = 6$
 $V_F = 3$

$$9 = 6 + \frac{3}{\mu}$$

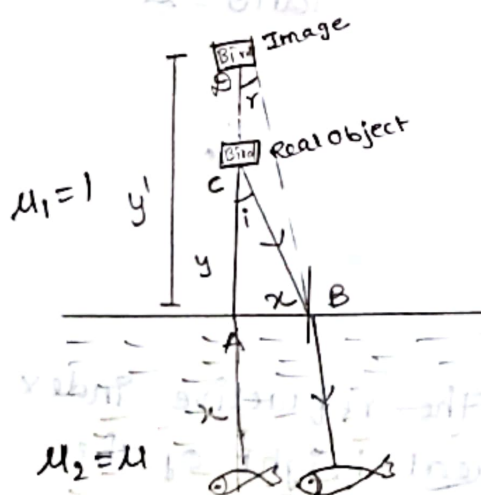
$$9 = \frac{6\mu + 3}{\mu} \Rightarrow 9\mu - 6\mu = 3$$

$$3\mu = 3$$

$$\mu = 1$$

* Apparent height :-

> A fish inside the liquid of refractive index ' μ '. A bird flying in air at a height ' y '. The apparent height of the bird is



From ΔABC

$$\tan i \approx \sin i \approx i \quad (\text{for small angles})$$

$$\tan i = \frac{x}{y}$$

$$\sin i = \frac{x}{y} \quad \text{--- (1)}$$

From ΔABD

$$\tan r \approx \sin r \approx r \quad (\text{for small angles})$$

$$\tan r = \frac{x}{y'}$$

$$\sin r = \frac{x}{y'} \quad \text{--- (2)}$$

By Snell's Law :-

$$\mu_1 \sin i = \mu_2 \sin r$$

$$(1) \frac{x}{y} = \mu \frac{x}{y'} \Rightarrow y' = \mu y$$

Application - 1 :-

A bird flying in air with height 'i'. A fish inside the liquid of refractive index ' μ '. The apparent shift is :-

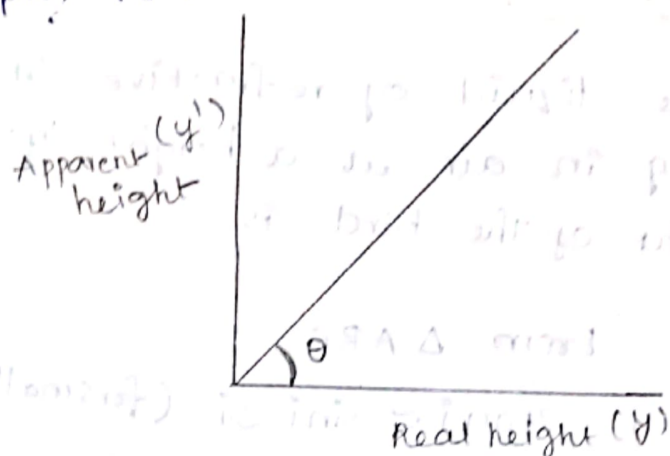
$$\text{Apparent shift} \Rightarrow \Delta y = y' - y$$

$$\Delta y = \mu y - y$$

$$\boxed{\Delta y = y(\mu - 1)} \checkmark$$

App-2 :- Graph :-

> A graph drawn b/w apparent height on y-axis & real height on x-axis then the nature of the graph is :-



$$\tan \theta = \frac{y'}{y}$$

$$\boxed{\tan \theta = \mu}$$

App-3 :-

> The depth of the fish 'x'. The refractive index of the medium is ' μ '. The real height of the bird is 'y'. The total apparent height of the bird seen by the fish.

The apparent height

$$h = x + y'$$

$$\star \boxed{h = x + \mu y}$$

or

$$\star \boxed{h = \mu y + x} \checkmark$$

APP-④:-

The velocity of the fish ' V_F '. The refractive index of the medium ' μ '. The velocity of the bird in air ' V_B '. The velocity of the bird seen by the fish (or) apparent velocity of the bird :-

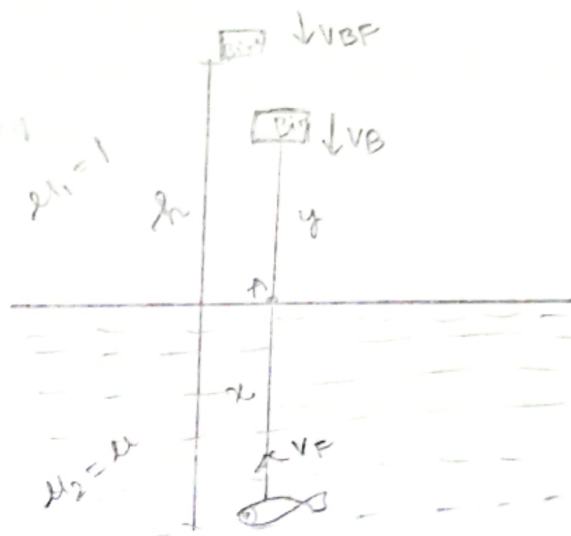
Total apparent height seen by the fish

$$h = \mu y + x$$

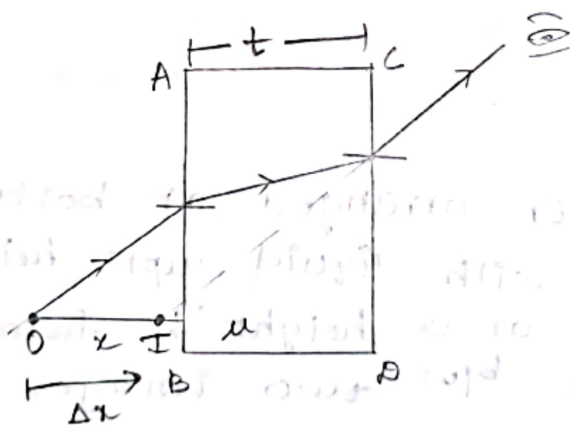
Differentiate w.r.to 't'

$$\frac{dh}{dt} = \mu \frac{dy}{dt} = \frac{dx}{dt}$$

$$V_{BF} = \mu V_B + V_F$$



➤ A glass slab of thickness ' t ', refractive index ' μ '. An object arranged at a distance ' x '. The position of the image

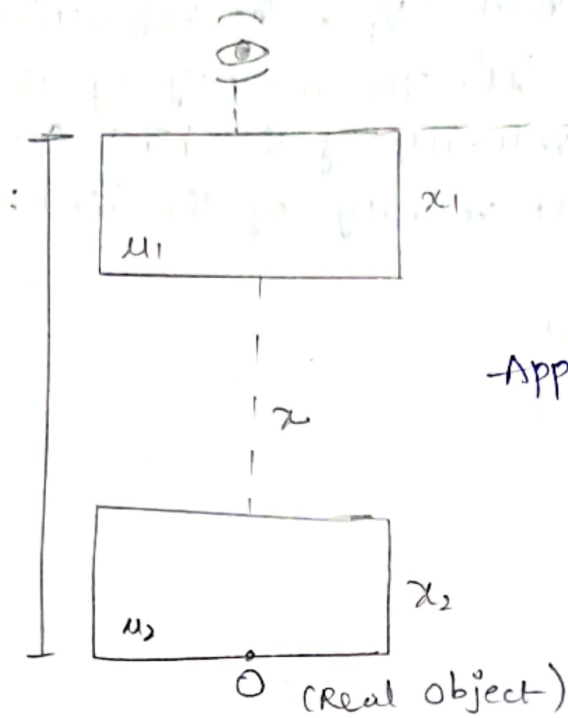


$$\text{Shift } (\Delta x) = t \left(1 - \frac{1}{\mu} \right)$$

APP-①:-

Two glass slabs each of thickness ' x_1 ' and ' x_2 '. Each of refractive index ' μ_1 ' & ' μ_2 '. An object arranged as shown in figure. The separation b/w the glass slab is ' x '. (i) The apparent depth of the object is

i) Apparent shift



Apparent depth

$$h' = \frac{x_1}{u_1} + x_2 + \frac{x_2}{u_2}$$

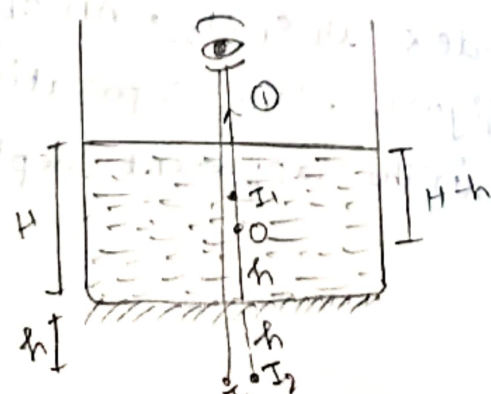
Apparent shift $\Delta h = h - h'$

$$\Delta h = x_1 + x_2 + x_2 - \frac{x_1}{u_1} - x_2 - \frac{x_2}{u_2}$$

$$\Delta h = x_1 + x_2 - \frac{x_1}{u_1} - \frac{x_2}{u_2}$$

$$\Delta h = x_1 \left(1 - \frac{1}{u_1}\right) + x_2 \left(1 - \frac{1}{u_2}\right)$$

→ (Q) A plane mirror arranged at bottom of the vessel filled with liquid upto height 'H'. An object arranged at a height 'h' from the mirror. The distance b/w two images when observer seen from the top.



Apparent depth $d_1 = \frac{H-h}{u}$

Apparent depth $d_2 = \frac{H+h}{u}$

Difference

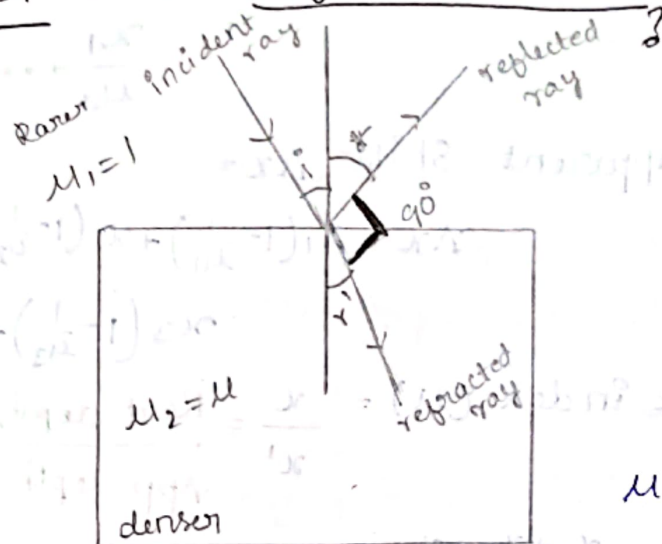
$$d_2 - d_1 = \frac{H+h}{u} - \frac{H-h}{u}$$

$$\Rightarrow \frac{2h}{u} = \frac{h+h}{u} = \frac{2h}{u}$$

15/04/2024 (Mon) :-

→ This model is ~~Patra~~ ✖✖

> (Q) A light ray incident at an angle i . A part of light is reflected & remaining part of light is refracted. The incident ray travel from rarer medium to denser medium. The refracted ray & reflected ray are mutually perp. The refractive index of the medium is



$$r + 90^\circ + r' = 180^\circ$$

$$r' = 180^\circ - 90^\circ - r$$

$$r' = 90^\circ - r \quad \checkmark$$

According to Snell's law:-

$$\mu_1 \sin i = \mu_2 \sin r'$$

$$(1) \sin i = \mu \sin(90^\circ - r)$$

$$\mu_1 \sin i = \mu_2 \sin r'$$

$$(1) \sin i = \mu \sin(90^\circ - r) \text{ (or)}$$

But; $L_i = L_r$

$$\sin i = \mu \cos r$$

$$\sin i = \mu \cos r$$

$$i = \sin^{-1}(\mu \cos r) \quad \checkmark$$

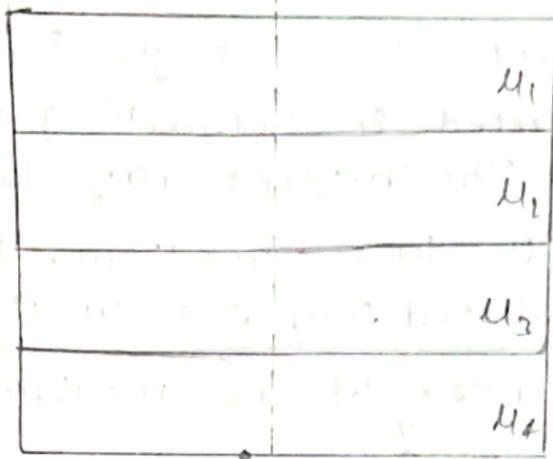
$$\mu = \tan i \quad \checkmark \checkmark$$

$$i = \sin^{-1}(\mu \sin r') \quad \checkmark$$

* Composite slabs :-

> Let 'n' no. of glass slabs each of refractive index $\mu_1, \mu_2, \mu_3 \dots$, each of thickness $x_1, x_2, x_3 \dots$. The apparent depth is :-

(ii) The effective refractive index



Real depth

$$x = x_1 + x_2 + x_3 + x_4 + \dots$$

① Apparent depth

$$x' = \frac{x_1}{\mu_1} + \frac{x_2}{\mu_2} + \frac{x_3}{\mu_3} + \frac{x_4}{\mu_4} + \dots$$

App. depth $d' = \frac{d}{\mu}$

② Apparent shift $\Delta x =$

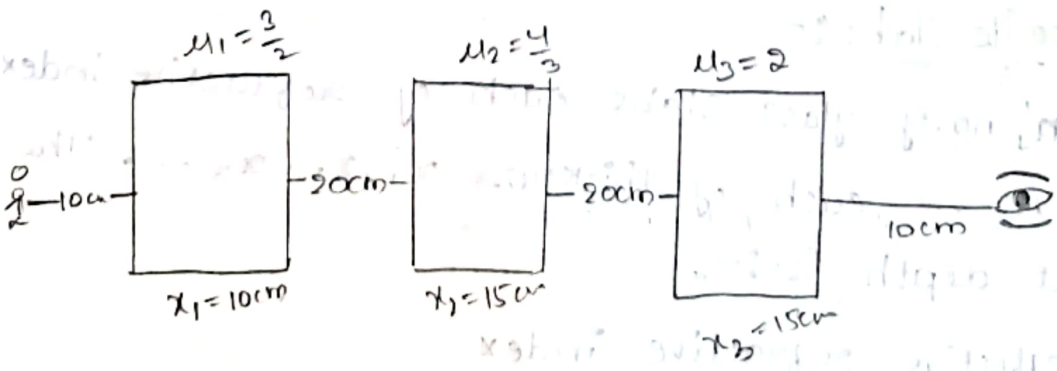
$$\Delta x = x_1 \left(1 - \frac{1}{\mu_1}\right) + x_2 \left(1 - \frac{1}{\mu_2}\right) + x_3 \left(1 - \frac{1}{\mu_3}\right) + \dots$$

③ effective refractive index (μ) = $\frac{x}{x'} = \frac{\text{Real depth}}{\text{App. depth}}$

$$\mu = \frac{x_1 + x_2 + x_3 + \dots}{\frac{x_1}{\mu_1} + \frac{x_2}{\mu_2} + \frac{x_3}{\mu_3} + \dots}$$

* (Q) If three slabs each of slab separated by the distance 20cm, each of refractive index $\frac{3}{2}$, $\frac{4}{3}$ & 2 respectively. Each of thickness 10cm, 15cm, 15cm respectively. The apparent shift is

→ App. shift depends on μ & thickness of the glass slab only



Apparent shift $\Delta x = x_1 \left(1 - \frac{1}{\mu_1}\right) + x_2 \left(1 - \frac{1}{\mu_2}\right) + x_3 \left(1 - \frac{1}{\mu_3}\right)$

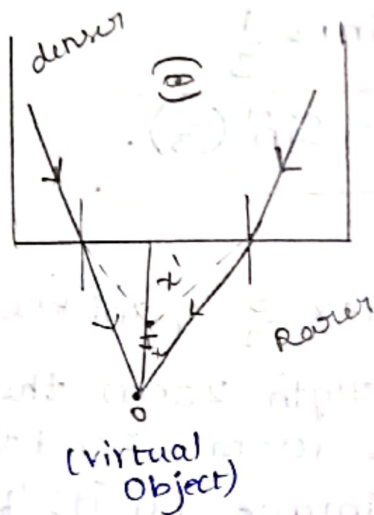
$$\Delta x = 10 \left(1 - \frac{2}{3}\right) + 15 \left(1 - \frac{3}{4}\right) + 15 \left(1 - \frac{1}{2}\right)$$

$$\Delta x = 10 \times \frac{1}{3} + 15 \times \frac{1}{4} + 15 \times \frac{1}{2}$$

$$\Delta x = 3.33 + 3.75 + 7.50$$

$$\Delta x = 14.58 \text{ cm} \quad \checkmark$$

> (Q) In convergent rays travel from denser to rarer medium it form the virtual object at a distance 'x'. The apparent shift in image



Real depth $d = x$

Apparent depth $d' = \frac{x}{\mu}$

shift $\Delta x = x \left(1 - \frac{1}{\mu}\right)$

> (Q) When convergent rays travel from rarer to denser medium the virtual object distance 'x'. The apparent shift in image.



Real depth $d = x$

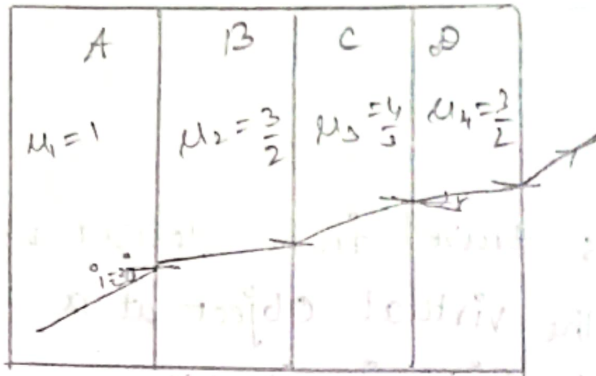
Apparent depth $d' = \mu x$

shift $\Delta x = \mu x - x$

$$\Delta x = \mu x - x$$

$$\Delta x = x(\mu - 1) \quad \checkmark$$

> (Q) The composite slabs each of refractive index $1, \frac{3}{2}, \frac{4}{3}, \frac{3}{2}$ respectively. The angle of incidence in first slab is 30° . The angle of refraction in slab D as show in figure



According to;
Snell's law:-

$$\mu \sin i = \text{constant}$$

$$\mu_1 \sin i = \mu_4 \sin r$$

$$(1) \sin 30^\circ = \frac{3}{2} \sin r$$

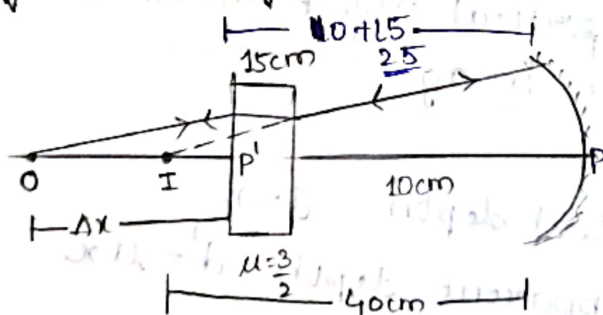
$$\frac{1}{2} = \frac{3}{2} \sin r$$

$$\sin r = \frac{1}{3}$$

$$r = \sin^{-1}\left(\frac{1}{3}\right)$$

Auto collimation:-

> (Q) A glass slab of refractive index $\frac{3}{2}$ & thickness 15cm. A concave mirror of focal length 20cm the distance b/w slab & mirror is 10cm. Find the position of the object form the image by itself from the glass slab.



Given;
 $f = 20\text{cm}$

$$R = 2f$$

$$R = 40\text{cm}$$

$$PI = 40\text{cm} = R$$

$$P'I = 40 - 25 = 15\text{cm}$$

$$\text{Apparent shift } (\Delta x) = t\left(1 - \frac{1}{\mu}\right)$$

$$\Delta x = 15\left(1 - \frac{2}{3}\right)$$

$$\Delta x = 15 \times \frac{1}{3} = 5\text{cm}$$

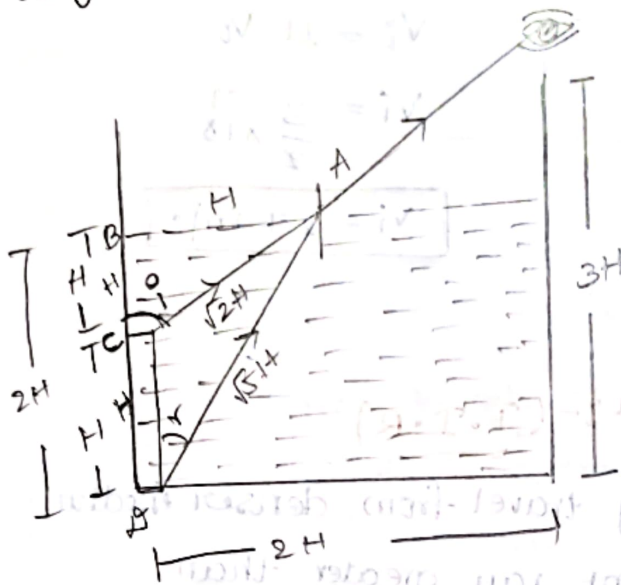
$$P'O = \Delta x + P'I$$

$$= 5 + 15$$

$$P'O = 20\text{cm}$$

- from the slab.

Q) A empty vessel of height $3h$. A linear object of height H is arranged one corner as show in figure. When it is observed it appears only at top. When it is filled with liquid upto height $2h$ it appears bottom of the rod. The refractive index of the liquid is



$$AD = \sqrt{(2H)^2 + H^2}$$

$$AD = \sqrt{5}H$$

From ΔABC

$$\sin i = \frac{H}{\sqrt{2}H}$$

$$\sin i = \frac{1}{\sqrt{2}} \quad \text{--- (1)}$$

From ΔABD

$$\sin r = \frac{H}{\sqrt{5}H}$$

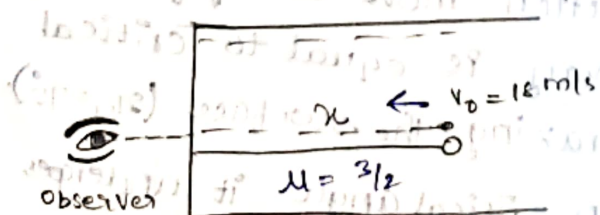
$$\sin r = \frac{1}{\sqrt{5}} \quad \text{--- (2)}$$

$$\mu_1 \sin i = \mu_2 \sin r$$

$$(1) \frac{1}{\sqrt{2}} = \mu \times \frac{1}{\sqrt{5}}$$

$$\mu = \sqrt{\frac{5}{2}}$$

Q) An object moving in medium with velocity 18 m/s . The refractive index of the medium $\frac{3}{2}$. The velocity of image as shown in figure.



$$\text{Apparent depth } x' = \frac{x}{\mu}$$

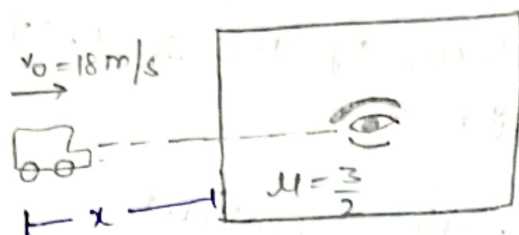
$$\frac{dx'}{dt} = \frac{1}{\mu} \frac{dx}{dt}$$

$$V_i = \frac{1}{\mu} v_o$$

$$V_i = \frac{2}{3} \times 18$$

$$V_i = 12 \text{ m/s}$$

> (Q) The velocity of the object is 18 m/s in air.
 An observer in denser medium of refractive index $\frac{3}{2}$.
 The velocity of the image is.



Apparent depth $x' = \mu x$

$$\frac{dx'}{dt} = \mu \frac{dx}{dt}$$

$$V_i = \mu V_o$$

$$V_i = \frac{3}{2} \times 18$$

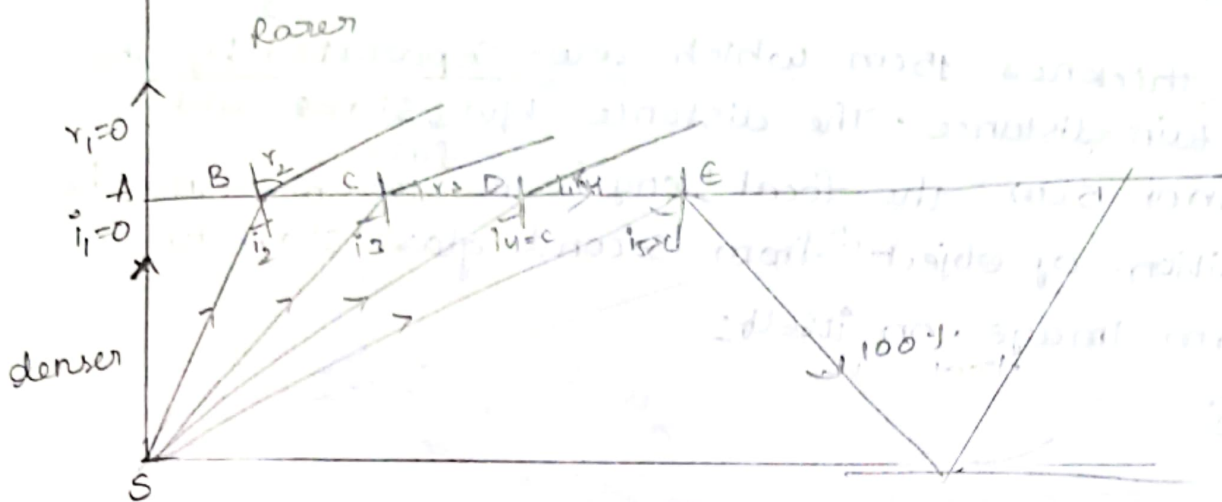
$$V_i = 27 \text{ m/s}$$

* Total Internal Reflection :- (T.I.R)

> Definition: When light ray travel from denser medium to rarer medium. If incident ray greater than critical angle. The reflected ray travel in same medium. This phenomenon is called Total Internal Reflection.

> Explanation:

→ At constant temperature, when light ray travel from denser medium to rarer medium along the path SA no deviation. If light ray travel along the path SB angle of refraction is r , with angle of incidence i . If angle of incidence increases angle of refraction move away from the normal. If incident ray is equal to critical angle the reflected ray grazing the surface ($\theta_r = 90^\circ$). If incident ray greater than critical angle it undergoes Total Internal Reflection as shown in figure.

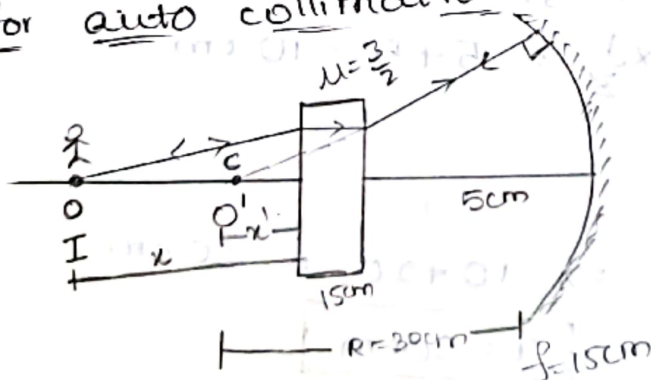


- In T.I.R intensity and energy of light remain constant.
- It produce brightest image.
- In T.I.R the nature of the image real, inverted and lateral.

16/04/2024 :- (Tue) :-

→ Ex for auto collimations :-

①



$$x = \Delta x + x' \\ = 5 + 10 = 15 \text{ cm} = x$$

$$x' + 15 + 5 = 30$$

$$x' = 30 - 20$$

$$x' = 10 \text{ cm}$$

$$\text{shift } \Delta x = t \left(1 - \frac{1}{n} \right)$$

$$\Delta x = 15 \left(1 - \frac{2}{3} \right)$$

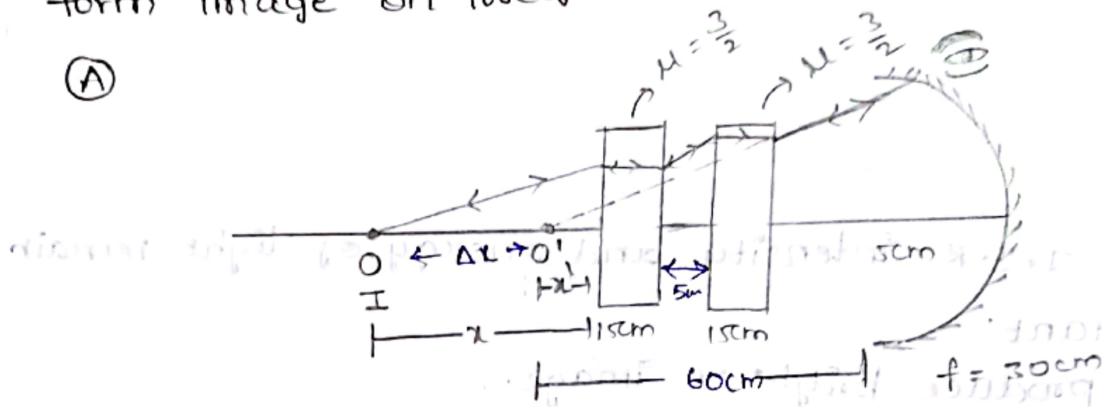
$$\Delta x = 15 \times \frac{1}{3}$$

$$\Delta x = 5 \text{ cm}$$

***Note:-** In auto collimation the image should be formed at centre of the spherical mirror.

⑤ A concave mirror of focal length 30cm. Two glass slabs each of refractive index $\frac{3}{2}$ and each of thickness 15cm which are separated by the certain distance. The distance b/w slabs and mirror 5cm the focal length is ^{first} 30cm. Find the position of object from second glass slab to form image on itself.

(A)



$$x' + 5 + 15 + 5 + 15 = 60$$

$$x' + 40 = 60$$

$$x' + 40 = 60 \Rightarrow x' = 60 - 40$$

$$x' = 20 \text{ cm}$$

$$\Delta x = 15 \left(1 - \frac{2}{3}\right) + 15 \left(1 - \frac{2}{3}\right)$$

$$= 15 \times \frac{1}{3} + 15 \times \frac{1}{3} = 5 + 5 = 10 \text{ cm}$$

$$\Delta x = 10 \text{ cm}$$

$$x = \Delta x + x' \Rightarrow 10 + 20 = 30 \text{ cm}$$

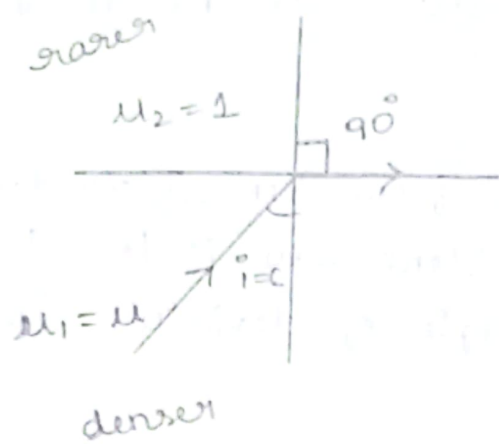
$$x = 30 \text{ cm}$$

* Critical Angle :- (vvi)

(c)

NCERT :-

> When light ray travel from denser medium to rarer medium at a particular angle of incidence the refracted ray makes 90° with the normal such angle of incidence is called Critical Angle (c).



→ Explanation:-

> The refractive index of the denser medium μ_1 ; the light ray enters into the rarer medium of refractive index μ_2 . If incident ray is equal to critical angle (c). According to Snell's law:-

$$\mu_1 \sin i = \mu_2 \sin r$$

But, $i = c$ then $r = 90^\circ$

$$\text{Then, } \mu_1 \sin c = \mu_2 \sin(90^\circ)$$

$$\mu_1 \sin c = \mu_2 (1)$$

$$\boxed{\sin c = \frac{\mu_2}{\mu_1}} \quad \text{For Adv. (VVI)}$$

But, $\mu_1 = \mu$; $\mu_2 = 1$

$$\boxed{\sin c = \frac{1}{\mu}} \quad \text{Mains & Board (VVE)}$$

App-①:-

> The light ray travel from denser medium to rarer medium with wavelength λ_1 and λ_2 respectively the critical angle is :-

$$\text{WKT, } \boxed{\mu \propto \frac{1}{\lambda}}$$

$$\mu \propto \frac{1}{v} \propto \frac{1}{\lambda}$$

$$\sin c = \frac{\mu_2}{\mu_1}$$

$$\frac{\mu_2}{\mu_1} = \frac{\lambda_1}{\lambda_2}$$

$$\boxed{\sin c = \frac{\lambda_1}{\lambda_2}}$$

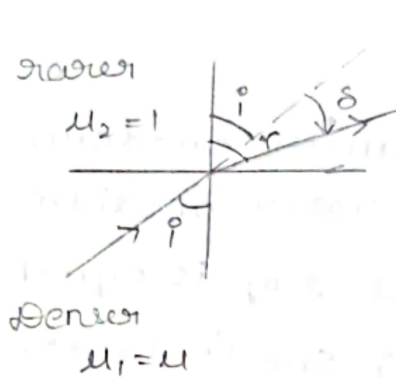
or

$$\boxed{\sin c = \frac{v_1}{v_2}}$$

* Angle of Deviation for critical angle:-

Case-(1)

> When light ray travel from denser medium to rarer medium if incident ray is less than critical angle. The angle of deviation is :-



$$r = i + \delta$$

$$\boxed{\delta = r - i} \rightarrow \text{Angle of deviation}$$

$$\mu_1 \sin i = \mu_2 \sin r$$

$$\mu \sin i = (1) \sin r$$

$$\sin r = \mu \sin i$$

$$\boxed{r = \sin^{-1}(\mu \sin i)}$$

$$\delta = r - i$$

$$\boxed{\delta = \sin^{-1}(\mu \sin i) - i}$$

* Note:-

Above equation represents non-linear equation.

Case-(2) *Jee-Mains* *pacca*

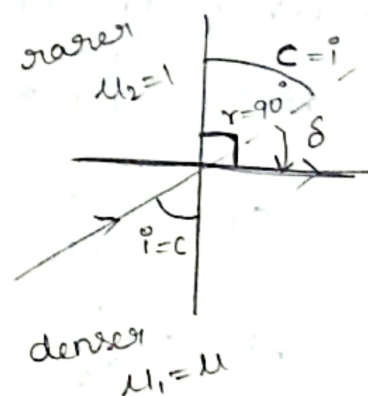
> When light ray travel from denser medium to rarer medium if incident ray is critical angle.

Find angle of deviation:-

$$r = c + \delta$$

$$\delta = r - c \quad \sqrt{\gamma}$$

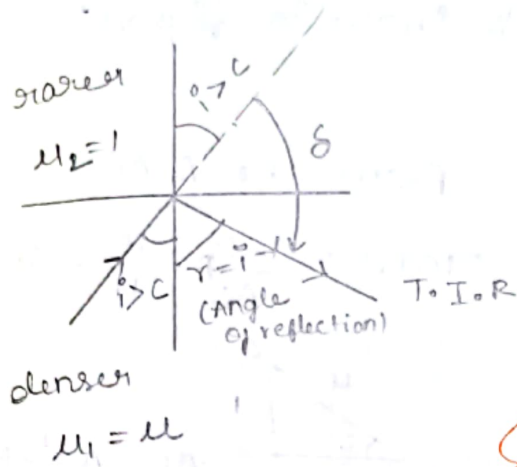
$$\boxed{\delta = \frac{\pi}{2} - c} \quad \text{or} \quad \boxed{\delta = 90^\circ - c}$$



$$\text{If } i = c \text{ then } \delta = \delta = \frac{\pi}{2} - c$$

Case-(3)

→ When light ray travel from denser to rarer medium. If incident ray is greater than critical angle. The angle of deviation is :-



$$\pi = i + i + \delta$$

$$\pi = 2i + \delta$$

$$\delta = \pi - 2i$$

or

$$\delta = \pi - 2C$$

ex:

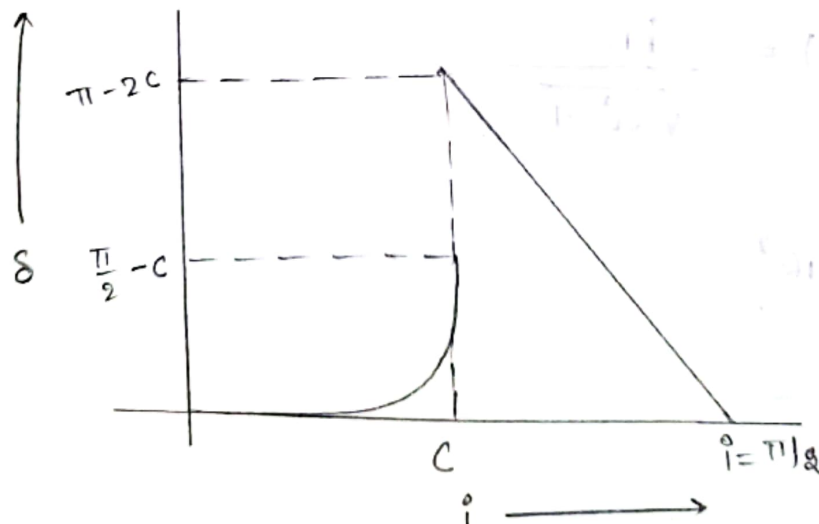
$$C = 45^\circ$$

$$i = 45.0001^\circ$$

→ also bend into same medium

* Graph :-

→ A graph drawn b/w angle of deviation on y-axis and angle of incidence on x-axis. The nature of the graph is :-



100-1.

पाँच (5)

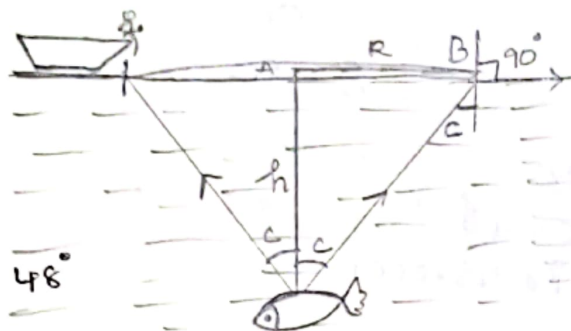
Ice-mains

Field

* Fish View of Vision of Fish *

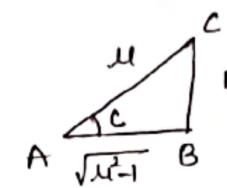
> A fish inside the water at a depth 'h', refractive index 'u'. The light rays move from fish to outer world like an inverted cone. As shown in figure:

① Vertex angle = $2c$



From the ΔABC

$$\tan c = \frac{AB}{AC} = \frac{R}{h} \quad \text{--- (1)}$$



$$AC^2 = AB^2 + BC^2$$

$$u^2 = (AB)^2 + (h)^2$$

$$\sin c = \frac{1}{u}$$

$$AB = \sqrt{u^2 - 1}$$

$$\tan c = \frac{1}{\sqrt{u^2 - 1}} \quad \text{--- (2)}$$

$$\frac{R}{h} = \frac{1}{\sqrt{u^2 - 1}}$$

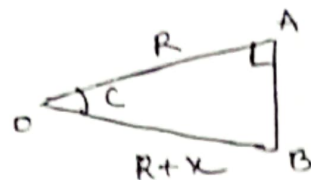
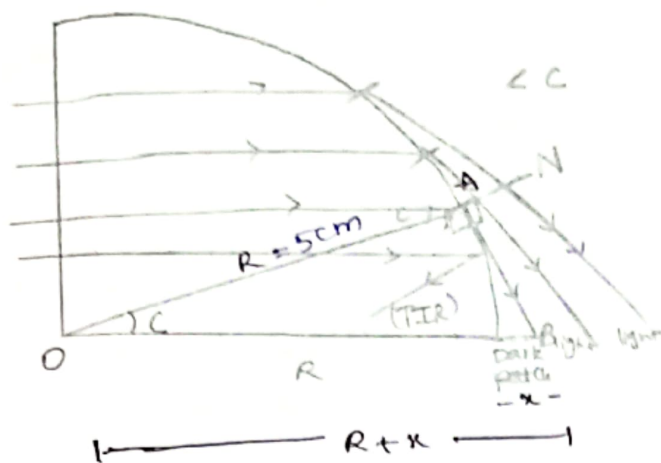
②

$$\text{Radius } (R) = \frac{h}{\sqrt{u^2 - 1}}$$

③ Area (A) = πR^2

$$A = \frac{\pi h^2}{u^2 - 1}$$

> (Q) A $\frac{1}{4}$ of cylinder of radius R ($R = 5\text{cm}$). The refractive index of the cylinder $\frac{2}{\sqrt{3}}$. When parallel rays incident on the cylinder how far distance the dark patch appeared?



$$\cos C = \frac{R}{R+x}$$

$$\text{But } \sin C = \frac{1}{\mu}$$

$$\sin C = \frac{1}{\frac{2}{\sqrt{3}}}$$

$$\sin C = \frac{\sqrt{3}}{2}$$

$$\boxed{C = 60^\circ}$$

$$\cos 60^\circ = \frac{R}{R+x}$$

$$\frac{1}{2} = \frac{R}{R+x}$$

$$R+x = 2R$$

$$x = 2R - R$$

$$\boxed{x = R}$$

$$\boxed{x = R = 5 \text{ cm}}$$

* Optical Fibre *

> Optical fibre cable made up of a plastic (or) glass (flint glass). The optical fibre based on the Total Internal Reflection.

> The optical fibre mainly consists three parts:-

(i) Core

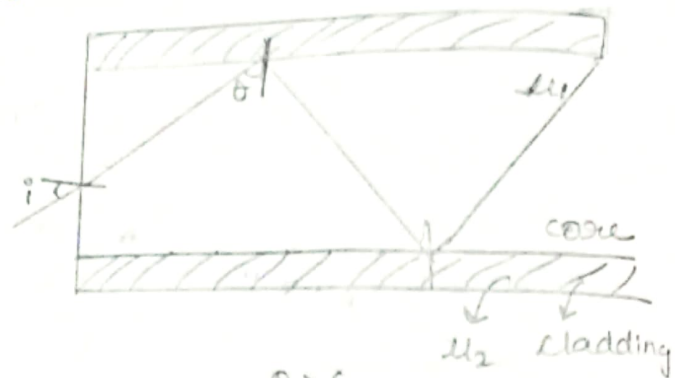
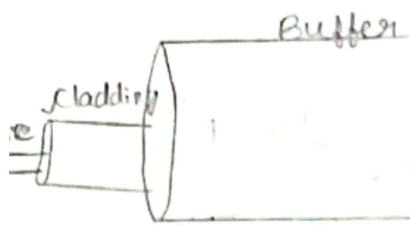
(ii) Cladding

(iii) Buffer.

> The core act as a denser medium & cladding act as a rarer medium.

> In optical fibre when light propagated from one end to another end no loss of energy as

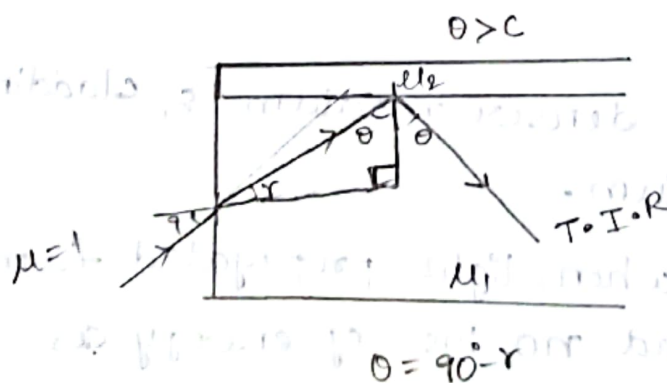
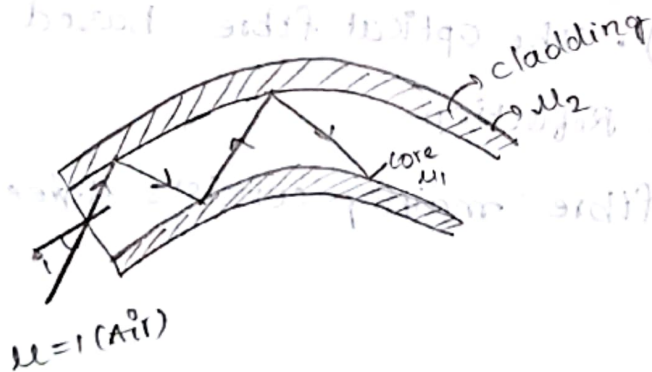
Show in figure :- (Till board level).



* The core refractive index is greater than cladding ($\mu_1 > \mu_2$)

18/04/2024 (Thu): * LAUNCHING ANGLE of Optical fibre *

> An optical fibre refractive index of the core μ_1 and refractive index of the cladding is μ_2 . The refractive index of the surrounding i.e. 1 (air). Find launching angle :-



$$\text{If } \theta > c$$

$$\sin \theta > \sin c$$

$$\sin(90^\circ - r) > \sin c$$

$$\cos r > \sin c$$

$$\sqrt{1 - \sin^2 r} > \sin c$$

$$\text{But } \sin c = \frac{\mu_2}{\mu_1}$$

$$\boxed{\sqrt{1 - \sin^2 r} > \frac{\mu_2}{\mu_1}} \quad \text{--- (1)}$$

According to Snell's law

$$\mu \sin i = \mu_1 \sin r$$

$$(1) \sin i = \mu_1 \sin r$$

$$\sin i = \mu_1 \sin r$$

$$\boxed{\sin r = \frac{\sin i}{\mu_1}} \quad \text{--- (2)}$$

$$\sqrt{1 - \frac{\sin^2 i}{\mu_1^2}} > \frac{\mu_2}{\mu_1}$$

$$1 - \frac{\sin^2 i}{\mu_1^2} > \frac{\mu_2^2}{\mu_1^2}$$

$$- \frac{\sin^2 i}{\mu_1^2} > \frac{\mu_2^2}{\mu_1^2} - 1$$

$$\frac{\sin^2 i}{\mu_1^2} > 1 - \frac{\mu_2^2}{\mu_1^2}$$

$$\sin^2 i > \mu_1^2 - \mu_2^2$$

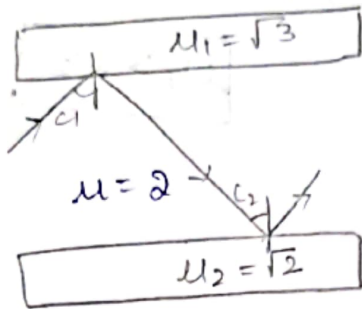
$$\boxed{\sin i > \sqrt{\mu_1^2 - \mu_2^2}}$$

For critical angle condition

$$\sin i = \sqrt{\mu_1^2 - \mu_2^2}$$

$$\boxed{i = \sin^{-1}(\sqrt{\mu_1^2 - \mu_2^2})}$$

Q) Cladding is made up of two different materials each of refractive index $\sqrt{3}$ and $\sqrt{2}$ as show in figure. The refractive index of the core is 2. Find min. angle of incidence for T.I.R.



PAR-1:-

$$\sin c_1 = \frac{\mu_1}{\mu}$$

$$\sin c_1 = \frac{\sqrt{3}}{2}$$

$$c_1 = 60^\circ$$

PAR-2:-

$$\sin c_2 = \frac{\mu_2}{\mu}$$

$$\sin c_2 = \frac{\sqrt{2}}{2}$$

$$\sin c_2 = \frac{1}{\sqrt{2}}$$

$$c_2 = 45^\circ$$

$i > 60^\circ$ then T.I.R happens.

(c)

$$\frac{\sin i}{\mu} = \sin c_2$$

$$\sin i < \sin c_2$$

$$\sin i < \sin c_2$$

angle of incidence is minimum

$$\sin i < \sin c_2$$

$$(\sin i)^2 < (\sin c_2)^2$$

$$\frac{\sin i}{\mu} < \frac{\sin c_2}{\mu}$$

$$\frac{\sin i}{\mu} < \frac{\sin c_2}{\mu}$$

$$1 - \frac{\sin i}{\mu} < 1 - \frac{\sin c_2}{\mu}$$

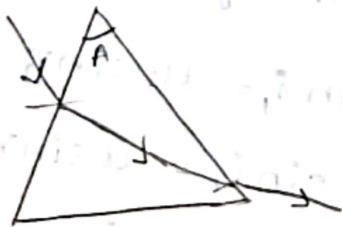
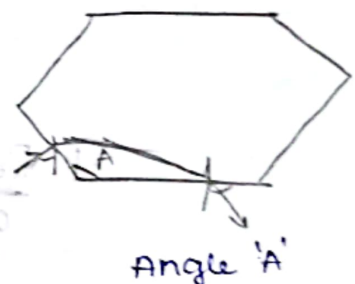
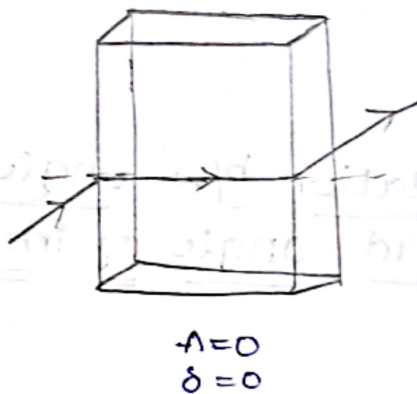
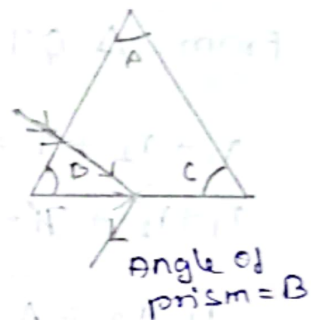
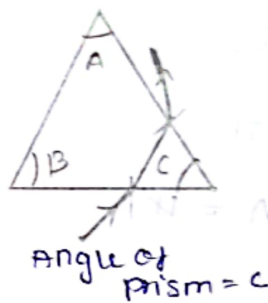
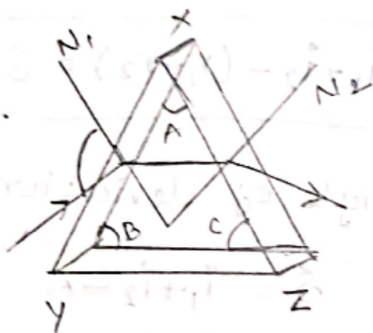
$$\frac{\sin i}{\mu} < \frac{\sin c_2}{\mu}$$

PRISM * (page one)

> A prism is made up flint glass or plastic where XYZ is called principle section of prism.

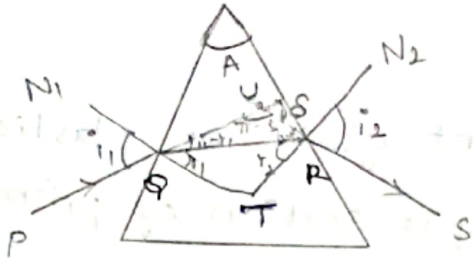
* Angle of prism :-

> The angle b/w any two refracting surfaces which allows incident ray and emergent ray is called Angle of prism. As show in figure.



* Derivation for prism formula (or) refractive index of prism :-

> An equilateral prism, of refractive index μ . Angle of prism 'A'. The angle of incidence ' i_1 ', angle of emergence ' i_2 '. The angle of refractions r_1 & r_2 as show in figure:-



$$U = \pi - \delta$$

$$Q = (i_1 - r_1) + (r_2)$$

$$R = (i_2 - r_2) + (r_2)$$

From the quadrilateral $PQRT$

$$A + T + Q + R = 360^\circ$$

$$A + T + 90^\circ + 90^\circ = 360^\circ$$

$$\boxed{A + T = 180^\circ} \quad \text{--- (1)}$$

From ΔQTR

$$r_1 + r_2 + T = \pi$$

$$r_1 + r_2 + \pi - A = \pi$$

$$* \quad \boxed{r_1 + r_2 = A}$$

VVI

From ΔUQR

$$\pi - \delta + i_1 - r_1 + i_2 - r_2 = \pi$$

$$\boxed{i_1 + i_2 - (r_1 + r_2) = \delta}$$

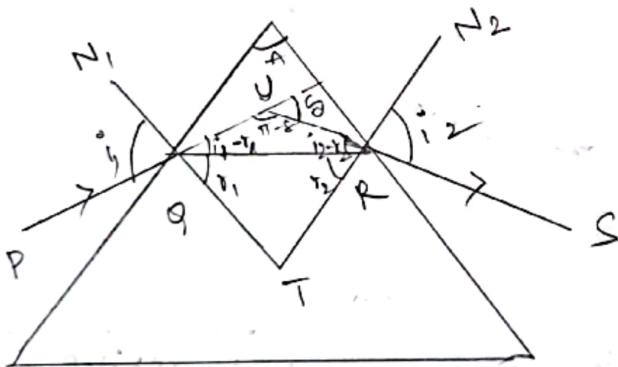
Angle of deviation

$$* \quad \boxed{\delta = i_1 + i_2 - A}$$

VVI

* Relation b/w angle of deviation
and angle of incidence *

↳ Non-linear eqn.



According to Snell's law:-

$$\mu_1 \sin i_1 = \mu_2 \sin r_1$$

$$(1) \sin i_1 = \mu \sin r_1$$

$$\boxed{\sin r_1 = \frac{\sin i_1}{\mu}}$$

According to Snell's law *

$$\mu \sin r_2 = \sin i_2$$

$$\sin i_2 = \mu \sin r_2$$

$$\boxed{i_2 = \sin^{-1}(\mu \sin r_2)} \quad *$$

But $\delta = i_1 + i_2 - A$

$$\delta = i_1 + \sin^{-1}(\mu \sin r_2) - A$$

$$r_1 + r_2 = A$$

$$r_2 = A - r_1$$

$$\delta = i_1 + \sin^{-1}(\mu \sin(A - r_1)) - A$$

$$\sin r_1 = \frac{\sin i_1}{\mu}$$

$$r_1 = \sin^{-1}\left(\frac{\sin i_1}{\mu}\right)$$

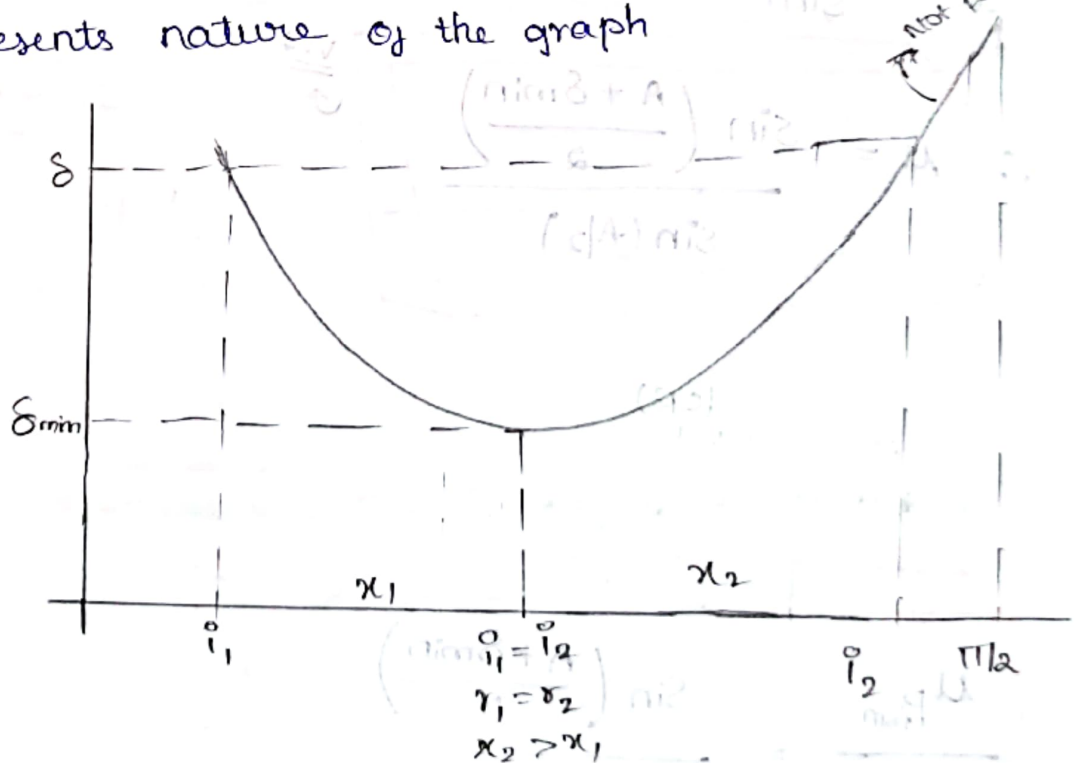
(Not-linear eqn)

$$\delta = i_1 + \sin^{-1}\left(\mu \sin\left(A - \sin^{-1}\left(\frac{\sin i_1}{\mu}\right)\right)\right) - A$$

(Not so *)

* Graph:-

> A graph drawn b/w angle of deviation on y-axis and angle of incidence on x-axis. It represents nature of the graph



At minimum deviation (δ_{min}) then

$$i_1 = i_2 = i \text{ and } r_1 = r_2 = r$$

> WKT $r_1 + r_2 = A$

If $r_1 = r_2 = r$

$r + r = A \Rightarrow 2r = A \Rightarrow$

$$r = \frac{A}{2}$$

> WKT,

$i_1 + i_2 = A + \delta$

If $i_1 = i_2 = i$

$i + i = A + \delta_{\min}$

$2i = A + \delta_{\min}$

$$i = \frac{A + \delta_{\min}}{2}$$

According to Snell's law:-

$$\frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r}$$

$$\therefore \mu = \frac{\sin \left(\frac{A + \delta_{\min}}{2} \right)}{\sin (A/2)}$$

$\frac{\mu_2}{\mu_1}$

In air
↓
prism

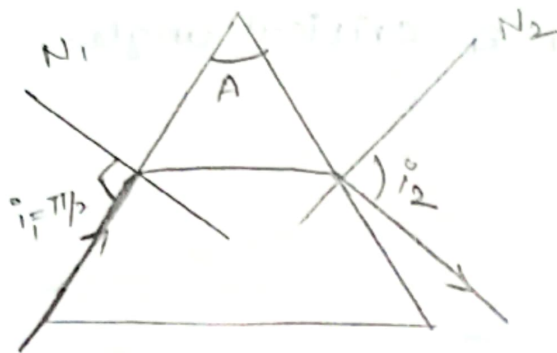
(OR)

If prism is dipped into the water :-

$$\frac{\mu_{\text{prism}}}{\mu_{\text{medium}}} = \frac{\sin \left(\frac{A + \delta_{\min}}{2} \right)}{\sin (A/2)}$$

Application (1) :-

> Condition for maximum angle of deviation



Angle of deviation of prism

$$\delta = i_1 + i_2 - A$$

If $i_1 = \pi/2$ then $\delta = \delta_{\max}$

$$* \boxed{\delta_{\max} = \frac{\pi}{2} + i_2 - A} *$$

App (2) :-

> Condition for limiting angle (or) Grazing incidence and Grazing emergence

→ An equilateral prism, of refractive index ' μ ' & angle of prism ' A ' find conditions for grazing incidence and grazing emergence.

$$i_1 = i_2 = \frac{\pi}{2}$$

$$r_1 = r_2 = C$$

$$(1) r_1 + r_2 = A$$

$$2C = A$$

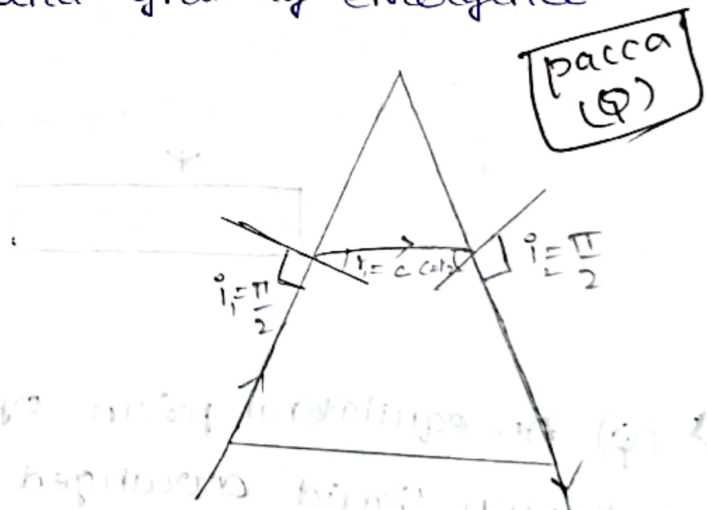
$$(2) \delta = i_1 + i_2 - A$$

$$\delta = \pi - A$$

$$(3) C = \frac{A}{2} \Rightarrow A = 2C$$

$$\sin C = \sin(A/2)$$

$$\frac{1}{\mu} = \sin\left(\frac{A}{2}\right) \Rightarrow \mu = \frac{1}{\sin\frac{A}{2}} \Rightarrow \mu = \csc\left(\frac{A}{2}\right)$$



App-③ :- (vvI) pacca 19

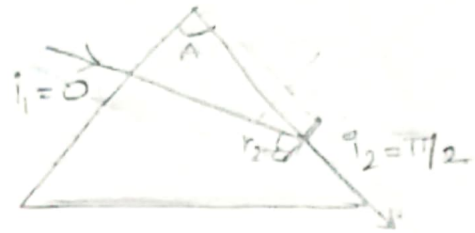
➤ When light ray incident normal to the surface & emergent ray grazing the other surface find relation b/w angle of prism & critical angle.

① $r_1 + r_2 = A$

$0 + C = A$

$C = A$

$i_1 = 0$
 $i_2 = \frac{\pi}{2}$



② $\delta = i_1 + i_2 - A$

$r_1 = 0$
 $r_2 = C$

$\delta = 0 + \frac{\pi}{2} - A$

* $\delta = \frac{\pi}{2} - A$ (Angle of deviation)

or
* $\delta = \frac{\pi}{2} - C$

③: $C = A$

$\sin A = \sin C$

$\sin A = \frac{1}{\mu}$

$\mu = \frac{1}{\sin A} \Rightarrow \mu = \operatorname{cosec} A$

$\frac{\pi}{2} = i_2 = i_c$
 $C = i_c = i_c$

➤ (Q) An equilateral prism of refractive index $\frac{3}{2}$. A unknown liquid arranged as show in figure. A light ray incident normally and it undergoes T to R.

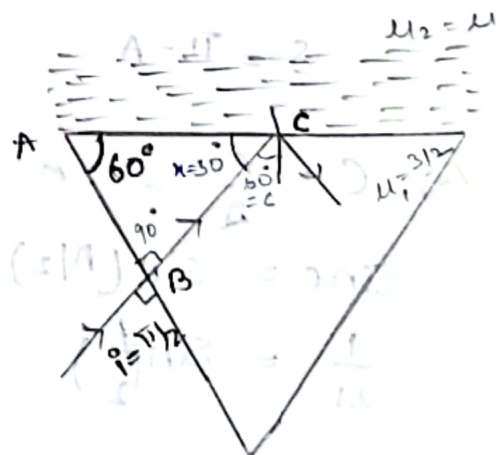
From ΔABC

$60^\circ + 90^\circ + x = 180^\circ$

$150^\circ + x = 180^\circ$

$x = 180^\circ - 150^\circ$

$x = 30^\circ$



critical angle $c = 60^\circ$ (From figure).

$$\sin c = \sin 60^\circ$$

$$\sin c = \frac{\sqrt{3}}{2}$$

$$\frac{\mu_2}{\mu_1} = \frac{\sqrt{3}}{2}$$

$$\frac{\mu_2}{3/2} = \frac{\sqrt{3}}{2}$$

$$\frac{2\mu_2}{3} = \frac{\sqrt{3}}{2}$$

$$3\sqrt{3} = 4\mu_2$$

$$\mu_2 = \frac{3\sqrt{3}}{4}$$

APP:-

* Condition for no emergence :- (T.I.R)

A small prism of refractive index μ . Angle of prism 'A'. The critical angle of the prism 'c' as show in figure.

*

$$r_2(\min) > c$$

$$r_1 + r_2 = A$$

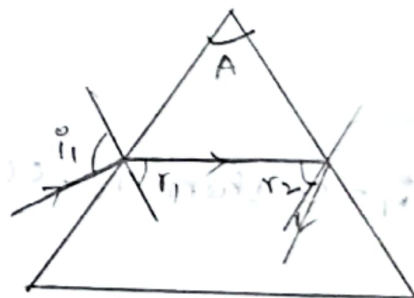
$$r_2(\min) = A - r_1(\max)$$

$$\text{If } i_1(\max) = \frac{\pi}{2}; r_1 = c$$

$$r_2(\min) = A - c$$

$$\text{But } r_2(\min) > c$$

$$A - c > c$$



*

$$A > 2C$$

$$\Rightarrow \frac{A}{2} > C$$

$$\sin\left(\frac{A}{2}\right) > \sin C$$

$$\sin \frac{A}{2} > \frac{1}{\mu}$$

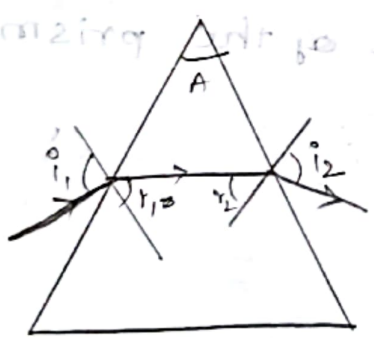
$$\mu > \frac{1}{\sin\left(\frac{A}{2}\right)}$$

$$\mu > \operatorname{cosec}\left(\frac{A}{2}\right)$$

App:-

* Condition for emergence any angle of incidence:-

> A prism refractive index ' μ '. Angle of prism ' A '. At any angle of incidence the light ray always emergent from the other surface.



$$C = 48^\circ$$

$$r_2 = 10^\circ, 15^\circ, 30^\circ, 46^\circ (\text{max}).$$

$$r_2(\text{max}) < C$$

$$r_1 + r_2 = A$$

If $i_1 = 0$ then $r_1 = 0 (\text{min})$

$$r_2(\text{max}) = A - r_1(\text{min})$$

If $i_1 = 0$, then $r_1 = 0 (\text{min})$

$$r_2(\text{max}) = A - 0$$

$$r_2(\text{max}) = A$$

But $r_2(\max) < C$

$$A < C$$

$$\sin A < \sin C$$

$$\sin A < \frac{1}{\mu}$$

$$\mu < \frac{1}{\sin A}$$

$$\mu < \operatorname{cosec} A$$

$$\mu < \sqrt{1 + \cos^2 A/2}$$

$\mu = \operatorname{cosec} A \rightarrow$ Grazing

19/04/2024 :- (Fri) :-

* App:-

> Condition for grazing emergent :-

$$r_1 + r_2 = A$$

$$r_2 = C$$

$$r_1 + C = A$$

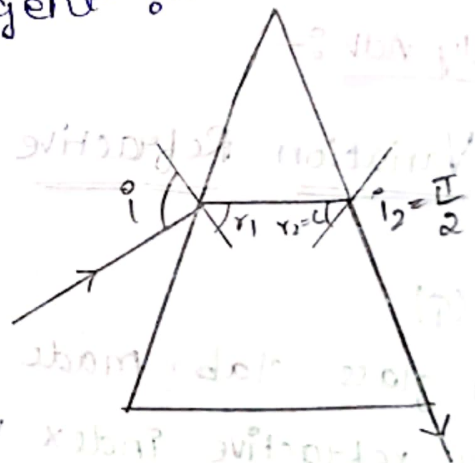
$$r_1 = A - C$$

Snell's law

$$\mu_1 \sin i_1 = \mu_2 \sin r_1$$

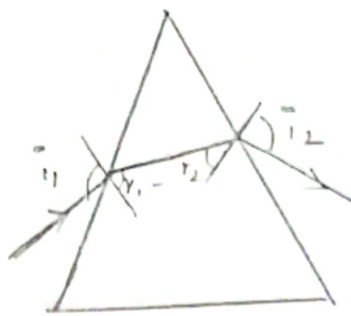
$$\mu \sin i_1 = \mu \sin(A - C)$$

$$i_1 = \sin^{-1}(\mu \sin(A - C))$$



* App:-

> Condition for angle of incidence for emergent ray out of the prism:-



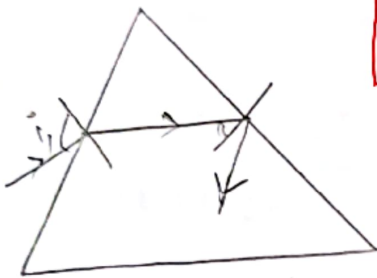
Angle of incidence $i_1 > \sin^{-1}(\mu \sin(A-c))$

$$i_1 > \sin^{-1}(\mu \sin(A-c))$$

* App:-

Condition for emergent ray undergoes T.I.R

Find angle of incidence is:-



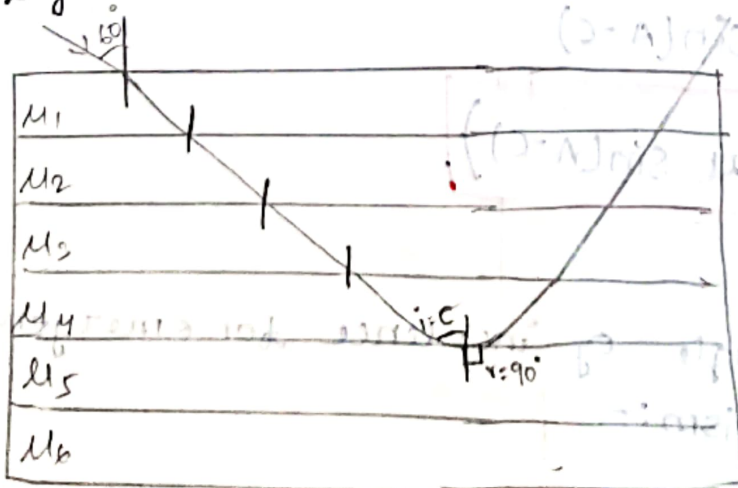
$$\text{Angle of incidence} < \sin^{-1}(\mu \sin(A-c))$$

only Adv :-

* Variation Refractive Index (R.I) with depth:-

> (Q)

A glass slab made up of different materials. The refractive index varies with depth $\mu = A - Bt$ (t = thickness). The max. distance travel by the light through the glass slab as show in figure.



Given:-

$$\mu = A - Bt$$

Snell's law:-

$$\mu_1 \sin i = \mu_2 \sin r$$

$$(1) \sin 60^\circ = \mu \sin 90^\circ$$

$$\sin 60^\circ = (A - Bt) (1)$$

$$\frac{\sqrt{3}}{2} = A - Bt$$

$$\frac{\sqrt{3}}{2} + Bt = A$$

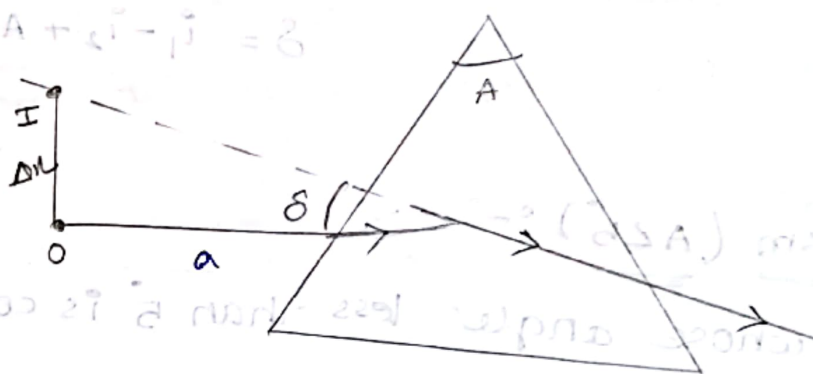
$$Bt = A - \frac{\sqrt{3}}{2}$$

$$* \quad t = \frac{1}{B} \left(A - \frac{\sqrt{3}}{2} \right)$$

∴ Formation of the image in prism:-
(OR)

∴ Apparent Shift in Prism:-

> A small glass prism of refractive index ' μ ' angle of prism ' A '. The object distance ' a '. The position of the image is



For small angles $\tan \delta = \delta$

$$\tan \delta = \frac{\Delta x}{a}$$

$$\delta = \frac{\Delta x}{a}$$

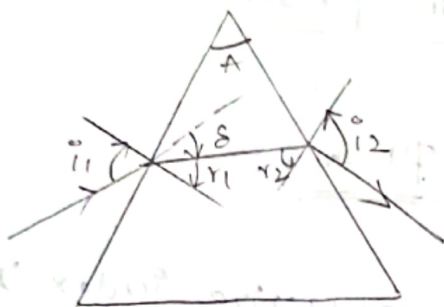
$$\text{Shift } \Delta x = \delta a$$

$$\text{Angle of deviation } \delta = (\mu - 1) A$$

$$\text{Apparant shift } \Delta x = (\mu - 1) A \cdot a$$

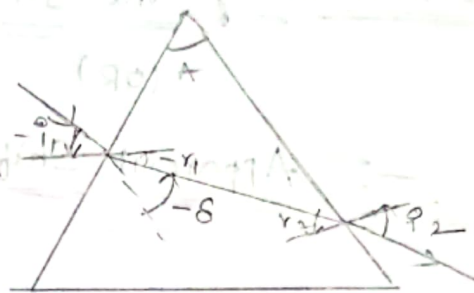
App:-

> A prism refracting angle or angle of prism 'A'. The angle of incidence and angle of emergence i_1 & i_2 . The angle of refractions r_1 & r_2 as shown in figure.



① $A = r_1 + r_2$

② $\delta = i_1 + i_2 - A$



① $A = r_2 - r_1$

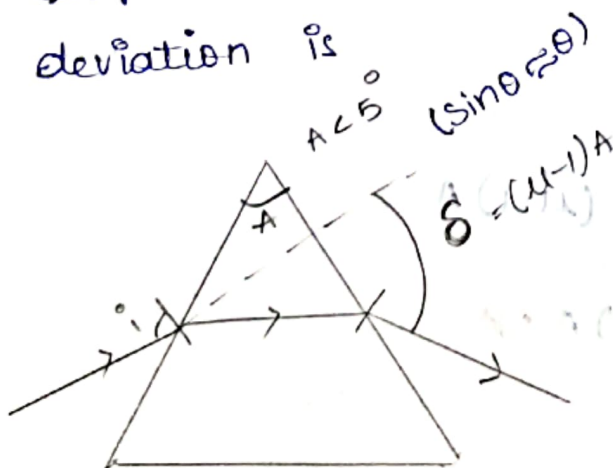
② $\delta = -i_1 + i_2 - A$

$\delta = i_1 - i_2 + A$

* Small prism ($A < 5^\circ$) :-

> A prism whose angle less than 5° is considered as a small prism.

> The refractive index of the prism is μ . And angle of the small prism is 'A'. The angle of deviation is



WKT,

R.I of prism $\mu = \frac{\sin\left(\frac{A + \delta_{\min}}{2}\right)}{\sin\frac{A}{2}}$

for small prism

$\sin\left(\frac{A + \delta_{\min}}{2}\right) = \frac{A + \delta_{\min}}{2}$

$$\sin\left(\frac{A}{2}\right) = \frac{A}{2}$$

$$\mu = \frac{A + \delta(\min)}{A}$$

$$\mu = \frac{A + \delta(\min)}{A}$$

$$\mu A = A + \delta(\min)$$

$$\delta(\min) = \mu A - A$$

$$\delta(\min) = A(\mu - 1)$$

* Note: The angle of deviation of the prism depends on refractive index and angle of prism. But it does not depend on angle of incidence.

$$\delta \propto \frac{1}{\lambda}$$

$$\delta \propto (\mu - 1)$$

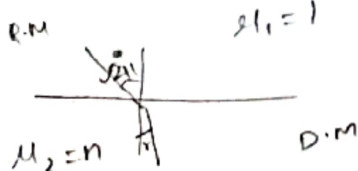
$$\delta \propto A$$

Module:

Pg: 104

(22) Short cut:

A ray of light passes from vacuum into a medium of refractive index n . If the angle of incidence is twice the angle of refraction, then the angle of incidence is:-



$$2r = i$$

$$(1) \sin i = n \sin r$$

$$r = \cos\left(\frac{i}{2}\right)$$

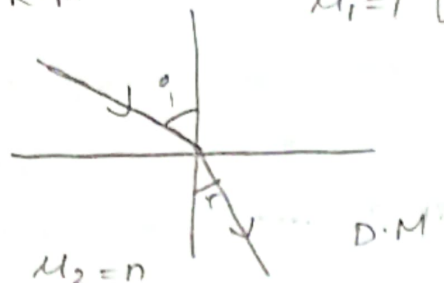
Ans

$$\cos r = \frac{n}{2}$$

R.M

$\mu_1 = 1$

$i = 2r$



WKT,

$i = 2r$

$$i = 2 \cos^{-1} \left(\frac{n}{2} \right)$$

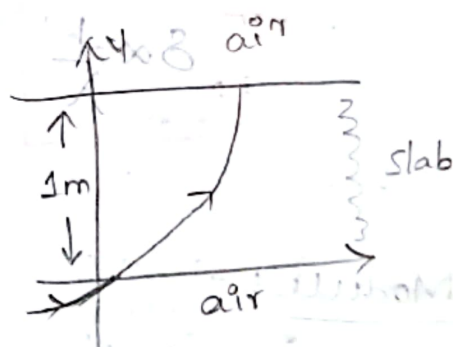
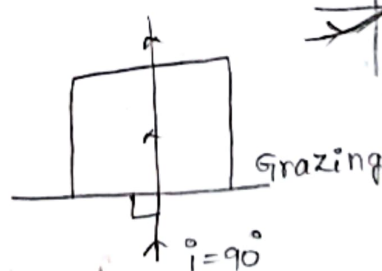
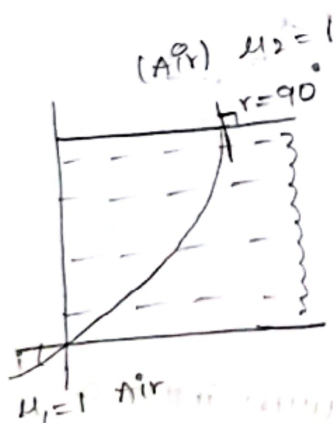
$\mu_1 \sin i = \mu_2 \sin r$

$(1) \sin(2r) = n \sin r$

$2 \sin r \cos r = n \sin r$

$$\cos r = \frac{n}{2} \Rightarrow r = \cos^{-1} \left(\frac{n}{2} \right)$$

(24) A ray of light travelling in air is incident at grazing incidence on a slab with variable refractive index $n(y) = [ky^{3/2} + 1]^{1/2}$ where $k = 1 \text{ m}^{-3/2}$ and follows path as shown in figure. What is the total deviation produced by the slab when the ray comes out.



Snell's law:-

$\mu_1 \sin i = \mu_2 \sin r$

$1 \times \sin i = (1) \sin 90^\circ$

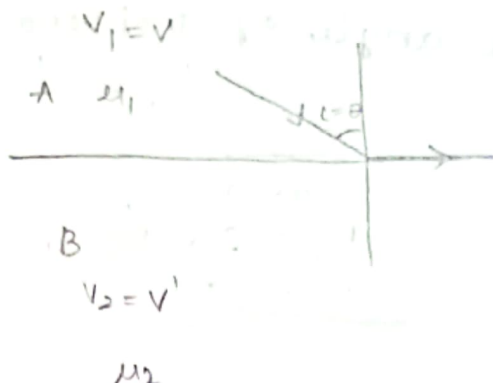
$\sin i = 1 \times 1$

$$i = 90^\circ$$

No deviation.

- (27) The critical from medium A to B is 0 . The speed of light in medium A is v . The speed of light in medium B is.

(A)



$$\sin c = \frac{\mu_2}{\mu_1}$$

$$\sin c = \frac{v_1}{v'}$$

$$v' \sin c = v_1$$

$$v' = \frac{v_1}{\sin c}$$

$$v' = \frac{v}{\sin c}$$

- (29) A prism of having refractive index $\sqrt{2}$ and refracting angle 30° , has one of the refracting surfaces polished. A beam of light incident on the other refracting surface will retrace its path if the angle of incidence is

$$r_1 + r_2 = A$$

$$r_1 + r_2 = 30^\circ$$

$$r_1 = 30^\circ$$

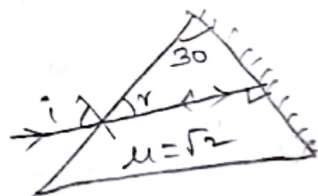
$$r_2 = 0$$

$$i_2 = 0$$

$$r_2 = 0$$

$$\mu_1 = 1$$

$$\mu_2 = \sqrt{2}$$



$$\mu_1 \sin i = \mu_2 \sin r$$

$$(1) \sin i = \sqrt{2} \sin 30^\circ$$

$$\sin i = \sqrt{2} \times \frac{1}{2}$$

$$\sin i = \frac{1}{\sqrt{2}}$$

$$i = 45^\circ$$

$$\mu_1 \sin i = \mu_2 \sin r$$

$$(1) \sin i = \sqrt{2} \frac{1}{2}$$

$$\sin i = \frac{1}{\sqrt{2}} \quad i = 45^\circ$$

19/4/24

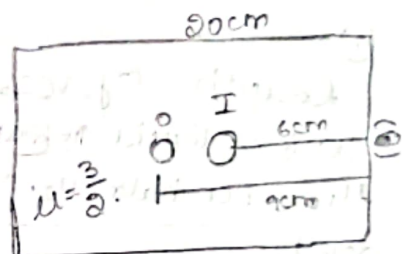
* classwork cont: *

> (Q) A glass slab of thickness 20cm. An air bubble appeared 6cm from one surface. The refractive index of the slab is $\frac{3}{2}$. The real position is.

$$\text{Apparent distance (x')} = \frac{\text{Real distance}}{\text{Refractive index}}$$

$$x' = \frac{x}{\mu}$$

$$6 = \frac{x}{\frac{3}{2}} \Rightarrow \frac{3}{2} = \frac{x}{6} \Rightarrow \boxed{x = 9 \text{ cm}}$$

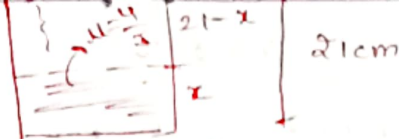


*

* MIRAGE * Board (4m).

> In hot summer days the temp. of the earth more & when you move away from the earth temperature decreases. Near the ground medium act as a rarer and away from the ground it act as a denser medium.

> When light ray travel from denser to rarer medium it undergoes total internal reflection. It form the inverted image as show in figure.



Apparent depth = $\frac{\text{real depth}}{\mu}$

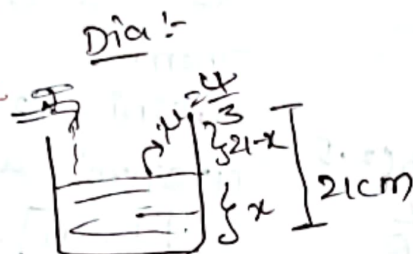
$$21 - x = \frac{x}{\mu}$$

$$21 - x = \frac{3x}{4}$$

$$84 - 4x = 3x$$

$$84 = 7x$$

$$x = 12 \text{ cm}$$



Q10 22/04/24 * Dispersion of light:- (Mon)

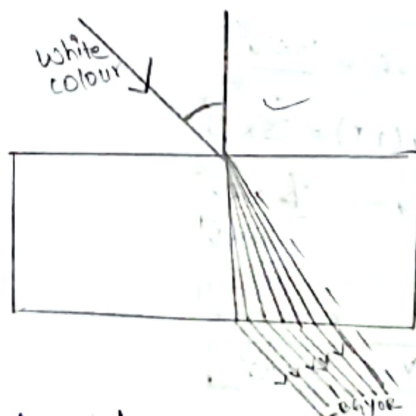
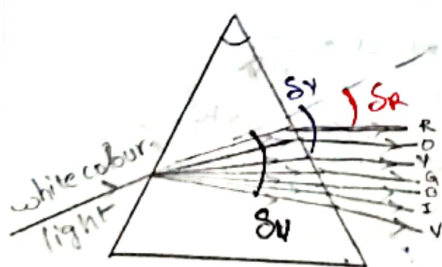
When white colour light passes through the prism or glass slab it can be split into different colours. (VIBGYOR). This phenomenon is called Dispersion of light. ✓

The dispersion depends on nature of the material.

The refractive index (μ) $\propto \frac{1}{\text{wavelength } (\lambda)}$ ✓

Angle of deviation for small prism

$$\delta = (\mu - 1)A$$



→ Angle of deviation for red colour

$$\delta_R = (\mu_R - 1)A$$

→ Angle of deviation for violet colour

$$\delta_V = (\mu_V - 1)A$$

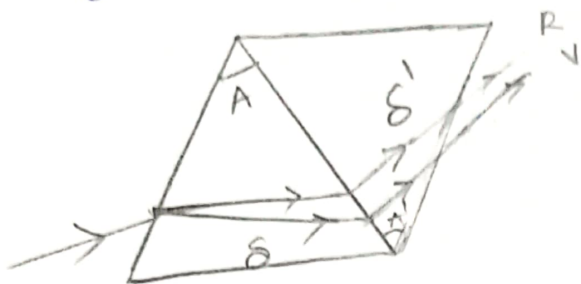
→ Angle of deviation for yellow colour

$$\delta_Y = (\mu_Y - 1)A$$

$$\delta_Y = \frac{\delta_V + \delta_R}{2}$$

* Condition for no deviation:-

Two small prisms each of angles A & A' . The refractive index μ and μ' . Find condition for no deviation:-



The net deviation $S_{net} = 0$

$$S + S' = 0$$

(OR)

$$\frac{\theta}{\omega} + \frac{\theta'}{\omega'} = 0$$

$$\frac{\theta}{\omega} = -\frac{\theta'}{\omega'}$$

$$S_{net} = 0$$

$$S_y + S'_y = 0$$

*

$$(\mu_y - 1)A + (\mu'_y - 1)A' = 0$$

⇒ Application-① :- A small prism, of refractive index μ and angle A . A small portion removed from the centre. Find angle of deviation & dispersive power.

Sol: When small portion removed from the prism it acts as a three parallel sheets. A parallel sheet does not provide dispersion & deviation. So $S = 0$ and $\theta = 0$



$$S = 0, \theta = 0, \omega = 0. \checkmark$$

$$S = 0$$

$$\theta = 0$$

$$\omega = 0.$$

* Angular Dispersion :- (θ)

> The difference b/w angle of deviation b/w the two extreme colours is called Angular dispersion. It is represented by ' θ '.

Angular dispersion $\theta = \delta_V - \delta_R$

WKT, $\delta_V = (\mu_V - 1)A$

$\delta_R = (\mu_R - 1)A$

$\theta = (\mu_V - 1)A - (\mu_R - 1)A$

$\theta = (\mu_V - \mu_R)A$

$\theta = (\mu_V - \mu_R)A$ ✓

$\delta_V = (\mu_V - 1)A$

$\delta_R = (\mu_R - 1)A$

$\delta_Y = (\mu_Y - 1)A$

$\delta_Y = \frac{\delta_V + \delta_R}{2}$

$\theta = \delta_V - \delta_R$

$\theta = (\mu_V - \mu_R)A$

$\omega = \theta / \delta_Y$

$\omega = \frac{\mu_V - \mu_R}{\mu_Y - 1}$

* Dispersive power :- (ω)

> The ratio of angular dispersion to mean deviation is called dispersive power. It is represented by ω .

Dispersive power (ω) = $\frac{\text{Angular dispersion } (\theta)}{\text{mean deviation } (\delta_{\text{mean}})}$

$\omega = \frac{\theta}{\delta_Y}$ ✓

$\Rightarrow \delta_{\text{mean}} = (\mu_Y - 1)A = \delta_Y$

Dispersive power (ω) = $\frac{\theta}{\delta_Y}$

$\omega = \frac{\delta_V - \delta_R}{\delta_Y}$ (OR) $\frac{\delta_V - \delta_R}{(\frac{\delta_V + \delta_R}{2})}$

$\omega = \frac{(\mu_V - 1)A - (\mu_R - 1)A}{(\mu_Y - 1)A}$

$\omega = \frac{\mu_V - \mu_R}{\mu_Y - 1}$

$\omega = \frac{\mu_V - \mu_R}{\mu_Y - 1}$ ✓

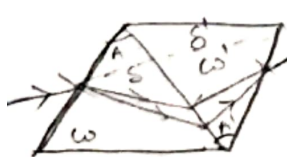
* Condition for no dispersion :-

net angular dispersion $\Rightarrow$
 $\theta_{\text{net}} = 0$; $\delta \neq 0$
 $\theta_1 + \theta_2 = 0$

$\omega_1 \delta_1 + \omega_2 \delta_2 = 0$

$\omega_1 \delta_1 = -\omega_2 \delta_2$

$\frac{\omega_1}{\omega_2} = -\frac{\delta_2}{\delta_1}$ ✓



No dispersion

$\theta = 0$ & $\delta \neq 0$

No deviation

$\delta = 0$ & $\theta \neq 0$

12/04/24 MON * Refraction through the Curved Surface *

> A curved surface of Radius of curvature (R). Refractive index is ' μ_2 '. An object (O) arranged in air of refractive index ' μ_1 '. It form the image other side of the object at a distance ' v ' as shown in figure:

$$PO = -u$$

$$PC = +R \text{ \& } PI = +v$$

From the ΔPMO

$$\tan \alpha = \frac{PM}{PO}$$

(for small angle
 $\tan \alpha \approx \alpha$) ✓

$$\alpha = \frac{PM}{PO} \text{ --- (1)}$$

From the ΔPMC

$$\tan \beta = \frac{PM}{PC}$$

$$\beta = \frac{PM}{PC} \text{ --- (2)}$$

From the triangle PMI

$$\tan \gamma = \frac{PM}{PI}$$

$$\gamma = \frac{PM}{PI} \text{ --- (3)}$$

But $\alpha + \beta = i$ and $\beta = r + \gamma$ ✓

$$\gamma = \beta - \alpha$$

According to Snell's law

$$\mu_1 \sin i = \mu_2 \sin r$$

for small angle

$$\mu_1 i = \mu_2 r$$

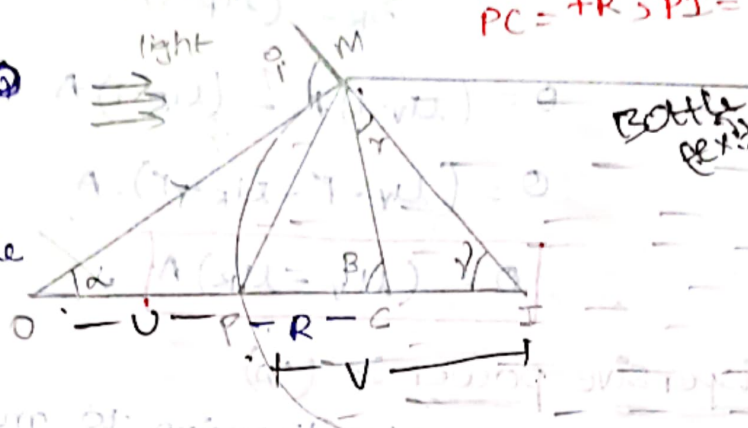
$$\mu_1 (\alpha + \beta) = \mu_2 (\beta - \gamma)$$

$$\mu_1 \alpha + \mu_1 \beta = \mu_2 \beta - \mu_2 \gamma$$

$$\mu_1 \alpha + \mu_2 \gamma = \mu_2 \beta - \mu_1 \beta$$

$$\mu_1 \alpha + \mu_2 \gamma = (\mu_2 - \mu_1) \beta$$

$$\mu_1 \left(\frac{PM}{PO} \right) + \mu_2 \left(\frac{PM}{PI} \right) = (\mu_2 - \mu_1) \frac{PM}{PC}$$

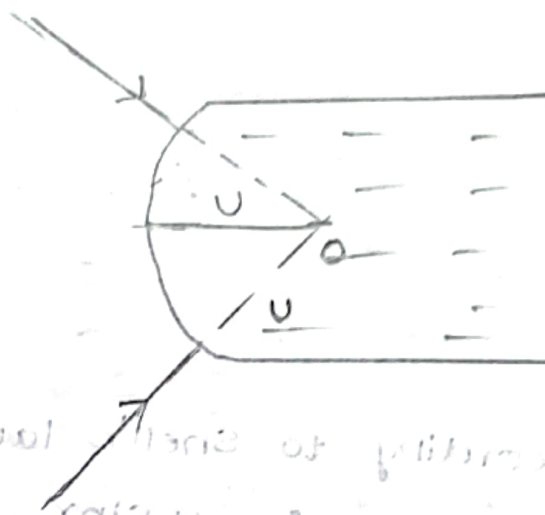


$$\frac{\mu_1}{-u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

* Note :- When light ray passes through the medium considered as a first medium.
 → When light ray enter into the medium considered as a second medium.

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$



23/04/2024 (Tue):

* Note :-

- In convex curved surface, when object at far distance it forms the real image.
- When object is near the curved surface (convex) it form the virtual image.
- In concave curved surface, real object produce virtual image only.

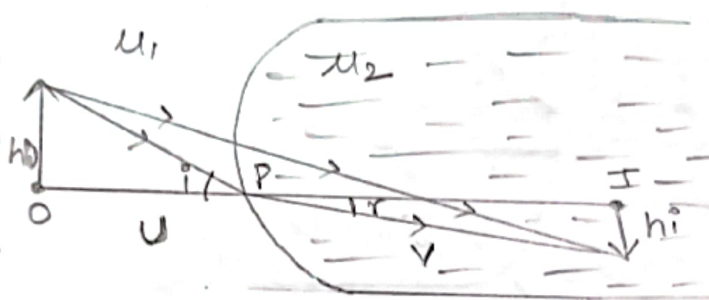
* Magnification :-

> The ratio of size of the image to size of the object is called Magnification.

$$> \text{Magnification (m)} = \frac{\text{size of image (hi)}}{\text{size of object (ho)}}$$

* Transverse Magnification (or) Lateral Magnification

> A curved refracting surface of radius of curvature (R). The refractive index of the medium (μ_1) & refractive index of the material (μ_2). The position of the object (u). It forms the image at a distance (v). The magnification is :-



$$m = \frac{h_i}{h_o}$$

for small angle

$$\tan i = \frac{h_o}{u} \approx i$$

$$\tan r = \frac{h_i}{v} \approx r$$

According to Snell's law

$$\mu_1 \sin i = \mu_2 \sin r$$

$$\mu_1 i = \mu_2 r$$

$$\mu_1 \frac{h_o}{u} = \mu_2 \frac{h_i}{v}$$

$$\frac{\mu_1}{\mu_2} \left(\frac{v}{u} \right) = \frac{h_i}{h_o}$$

$$\text{Magnification (m)}_T = \frac{h_i}{h_o} = \frac{\mu_1}{\mu_2} \left(\frac{v}{u} \right)$$

→ Application - (1) :-

> ^{AN} Object ~~has~~ height (h_o) moving with constant speed (v_o) per to the principle axis. The refractive index of the medium μ_1 and μ_2 . The speed of the image with respect to curved surface

(or) speed of axis

$$\frac{h_i}{h_o} = \frac{\mu_1}{\mu_2} \left(\frac{v}{u} \right)$$

$$h_i = \frac{\mu_1}{\mu_2} \left(\frac{v}{u} \right) h_o$$

Differentiation w.r.to 't'.

$$\frac{dh_i}{dt} = \frac{\mu_1}{\mu_2} \left(\frac{v}{u} \right) \frac{dh_o}{dt}$$

$$V_i = \frac{\mu_1}{\mu_2} \left(\frac{v}{u} \right) V_o$$

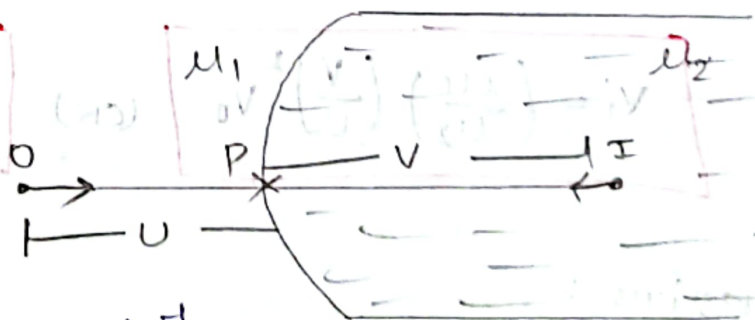
(OR)

$$V_{ic} = \frac{\mu_1}{\mu_2} \left(\frac{v}{u} \right) V_{oc}$$

* Longitudinal Magnification:-

Let an object moving along the principle axis at a given instant of time. The position of the object is (u). In medium of refractive index (μ_1). The position of the image (v). In second medium of refractive index (μ_2). The longitudinal magnification is

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$



$$\mu_2 \vec{v}^{-1} - \mu_1 \vec{u}^{-1} = (\mu_2 - \mu_1) \vec{R}^{-1}$$

$$\mu_2 (-1) \vec{v}^{-2} \frac{dv}{dt} - \mu_1 (-1) \vec{u}^{-2} \frac{du}{dt} = 0$$

$$-\frac{\mu_2}{v^2} \frac{dv}{dt} + \frac{\mu_1}{u^2} \frac{du}{dt} = 0$$

$$\pm \frac{\mu_2}{v^2} dv = \pm \frac{\mu_1}{u^2} du$$

$$\frac{dv}{du} = \frac{\mu_1}{\mu_2} \left(\frac{v}{u} \right)^2$$

$$m_L = \frac{\mu_1}{\mu_2} \left(\frac{v}{u} \right)^2$$

App-①:

> (Q) A object is moving with velocity v_0 in medium μ_1 . And velocity of the image in second medium μ_2 is :-

$$m_L = \frac{dv}{du}$$

$$\frac{dv}{du} = \left(\frac{\mu_1}{\mu_2} \right) \left(\frac{v}{u} \right)^2$$

$$\frac{dv}{du}$$

$$dv = \left(\frac{\mu_1}{\mu_2} \right) \left(\frac{v}{u} \right)^2 du$$

Differentiation w.r. to 't'

$$\frac{dv}{dt} = \left(\frac{\mu_1}{\mu_2} \right) \left(\frac{v}{u} \right)^2 \frac{du}{dt}$$

$$v_i = \left(\frac{\mu_1}{\mu_2} \right) \left(\frac{v}{u} \right)^2 v_0$$

(OR)

$$v_{ic} = \left(\frac{\mu_1}{\mu_2} \right) \left(\frac{v}{u} \right)^2 v_{oc}$$

Questions :

Q₁) A white light passes through the prism of angle 5° . The refractive index for red & blue colours $\mu_R = 1.641$; $\mu_B = 1.659$. The angle of dispersion b/w the colours.

$$\text{Angular dispersion } (\theta) = \delta_B - \delta_R$$

$$\theta = (\mu_B - 1)A - (\mu_R - 1)A$$

$$\theta = (\mu_B - \mu_R)A$$

$$\theta = (1.659 - 1.641) 5^\circ$$

$$\theta = 0.018 \times 5^\circ$$

$$\boxed{\theta = 0.09^\circ} \checkmark$$

Q) The refractive index of flint glass prism for C, D, F lines are 1.790, 1.795, 1.805. Find dispersive power of flint prism.

$$\text{Dispersive power } (\omega) = \frac{\theta}{\delta_y} \quad \mu_C = 1.790$$

$$\mu_D = 1.795$$

$$\mu_F = 1.805$$

$$\omega = \frac{(\mu_F - \mu_C)A}{(\mu_D - 1)A}$$

$$= \frac{1.805 - 1.790}{(1.795 - 1)}$$

$$= \frac{0.015}{0.795}$$

$$= 0.0187 \checkmark$$

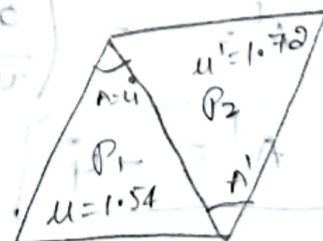
$$\omega = \frac{0.015}{0.795} = 0.0187 \checkmark$$

$$\begin{array}{r} 1.805 \\ - 1.790 \\ \hline 0.015 \\ 1.795 \\ - 1.000 \\ \hline 0.795 \end{array}$$

Q3) A thin prism (P_1) with angle 4° made up of glass with refractive index 1.54. It is combined with another glass prism (P_2) with R.I 1.72. It produce without deviation with dispersion. The angle of prism (P_2) is

NO deviation

$$\delta_{\text{net}} = \delta_1 + \delta_2 = 0$$



$$(\mu-1)A + (\mu'-1)A' = 0$$

$$(1.54-1) \times 4 + (1.72-1) \cdot A' = 0$$

$$(0.54) \times 4 + (0.72) A' = 0$$

$$A' = - \left(\frac{0.54 \times 4}{0.72} \right)$$

$$A' = -3^\circ$$

Note: where 've' sign indicates opposite to the first prism and angle of prism 3°

Q4) A crown glass prism angle of refraction 8° is combined with flint glass to obtain deviation without dispersion. The refractive index red & violet rays for flint glass 1.645 and 1.665. And for crown glass refractive index 1.514 and 1.524. Find angle of flint glass

(b) Find net deviation.

Condition for no dispersion

$$\theta_{\text{net}} = \theta \quad \theta = (\mu_v - \mu_r)A$$

$$\theta_{\text{net}} = \theta_1 + \theta_2 = 0$$

$$\delta = (\mu-1)A$$

$$\Rightarrow (\mu_v - \mu_r)A + (\mu'_v - \mu'_r)A' = 0$$

$\Rightarrow$ here

$$(1.524 - 1.514) 8^\circ + (1.665 - 1.645) A' = 0$$

$$\Rightarrow 0.010 \times 8^\circ + 0.020 \times A' = 0$$

$$\Rightarrow A' = - \left(\frac{0.010 \times 8}{0.020} \right)$$

$$A' = -4^\circ$$

$$\mu_v = 1.524$$

$$\mu_r = 1.514$$

$$A = 8^\circ$$

$$\mu'_r = 1.645$$

$$\mu'_v = 1.665$$

$$A' =$$

Net deviation $\delta_{\text{net}} = \delta_1 + \delta_2$

$$\delta_{\text{net}} = (\mu_y - 1)A + (\mu'_y - 1)A'$$

$$\mu_y = \frac{\mu_v + \mu_R}{2}$$

$$\mu'_y = \frac{\mu'_v + \mu'_R}{2}$$

$$\mu_y = \frac{1.524 + 1.514}{2}$$

$$\mu'_y = \frac{1.665 + 1.645}{2}$$

$$\mu_y = \frac{1.519}{2}$$

$$\mu'_y = \frac{1.655}{2}$$

$$\mu_y = 1.519$$

$$\mu'_y = 1.655$$

$$A = 8^\circ$$

$$A' = -4^\circ$$

$$\delta_{\text{net}} = (\mu_y - 1)A + (\mu'_y - 1)A'$$

$$= (1.519 - 1)8 + (1.655 - 1)(-4)$$

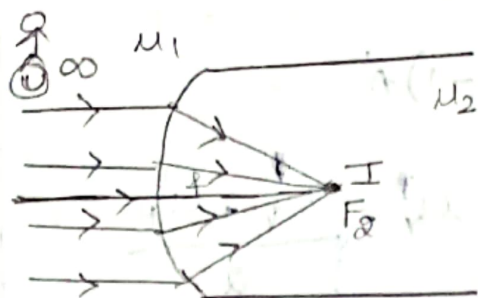
$$= (0.519)8 - (0.655)4$$

$$= 4.152 - 2.62$$

$$\delta_{\text{net}} = 1.53^\circ$$

* Principal Foci *

> When object arranged at ' ∞ ' distance it forms the image in second medium. The focal length becomes ' f_2 '. When obj arranged in first medium at a distance ' f_1 ' it forms the image in second medium at ' ∞ ' distance as shown in figure:



Case - (1) :

$$u = \infty ; v = f_2$$

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{\mu_2}{f_2} - \frac{\mu_1}{\infty} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{\mu_2}{f_2} = \frac{\mu_2 - \mu_1}{R} + \mu_1 \left(\frac{1}{f_1} \right) = \frac{-\mu_2 - \mu_1}{R}$$

$$\frac{f_2}{\mu_2} = \frac{R}{\mu_2 - \mu_1}$$

$$f_2 = \frac{\mu_2 R}{\mu_2 - \mu_1}$$

Case - (2) :

$$u = \infty ; v = f_1$$

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{\mu_2}{\infty} - \frac{\mu_1}{f_1} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{f_1}{\mu_1} = \frac{-R}{\mu_2 - \mu_1}$$

$$f_1 = \frac{-\mu_1 R}{\mu_2 - \mu_1}$$

$$\therefore f_1 \neq f_2$$

24/04/2024 : (Wed)

* Reduced Focal length :-

> The ratio of focal length to refractive index in same medium is called Reduced focal length.

(OR)

> The ratio of distance travelled by the light in vacuum to refractive index of the medium is called Reduced focal length.

$$> \text{Reduced focal length (R.F)} = \frac{-\text{focal length (f)}}{\text{Refractive index } (\mu)}$$

$$R.F = \frac{f_1}{\mu_1} \quad \checkmark$$

$$R.F = \frac{-R}{\mu_2 - \mu_1} \quad \text{--- (1)}$$

WKT

$$f_1 = \frac{-\mu_1 R}{\mu_2 - \mu_1} \Rightarrow \frac{f_1}{\mu_1} = \frac{-R}{\mu_2 - \mu_1}$$

$$f_2 = \frac{\mu_2 R}{\mu_2 - \mu_1} \Rightarrow \frac{f_2}{\mu_2} = \frac{R}{\mu_2 - \mu_1}$$

* Power due to curved surface :-

$$> \text{power is } \propto \frac{1}{\text{Reduced focal length (R.F)}} \quad \checkmark$$

As $R.F = \frac{f}{\mu}$

Then

$$P = \frac{\mu}{f} \quad \checkmark$$

$$P = \frac{\mu_1}{f_1} = -\frac{\mu_2}{f_2} \quad \checkmark$$

$$P = -\left(\frac{\mu_2 - \mu_1}{R}\right) \quad *$$

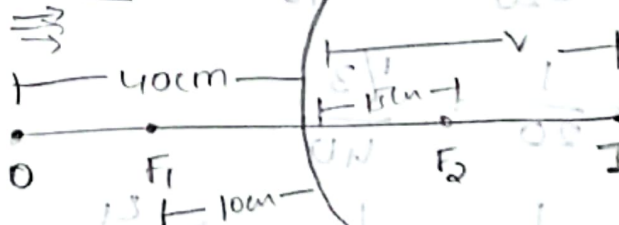
(From (1)) (reciprocal).

* Note :-

WKT,

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

Q:-



$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{f_1}{u} + \frac{f_2}{v} = 1$$

$$\frac{\mu_2 R}{v(\mu_2 - \mu_1)} - \frac{\mu_1 R}{u(\mu_2 - \mu_1)} = 1$$

$$\frac{f_1}{u} + \frac{f_2}{v} = 1$$

$$\frac{f_2}{v} - \frac{-f_1}{u} = 1$$

$$\frac{f_2}{v} + \frac{f_1}{u} = 1$$

$$\boxed{\frac{f_1}{u} + \frac{f_2}{v} = 1} *$$

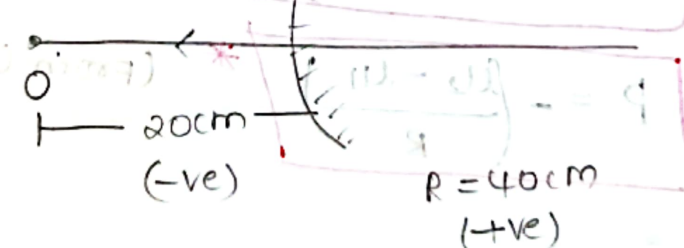
Q₁) An object is placed at a distance 20 cm from the convex spherical surface. The refractive index surrounding is 1 and refractive index of the material is $\frac{4}{3}$. The radius of curvature is 40 cm. Find position of the image.

$\Rightarrow (+ve)$
 $\mu_1 = 1$

$$\mu_2 = \frac{4}{3} = 1.33$$

WKT,

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$



$$\frac{4}{3v} - \frac{1}{-20} = \frac{4/3 - 1}{40}$$

$$\frac{4}{3v} + \frac{1}{20} = \frac{1/3}{40}$$

$$\frac{4}{3v} + \frac{1}{20} = \frac{1}{120} \Rightarrow \frac{4}{3v} = \frac{1}{120} - \frac{1}{20}$$

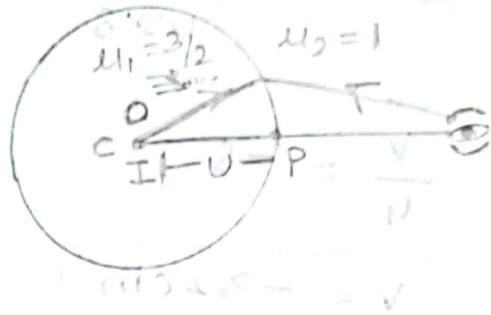
Q3) A point object is placed at the centre of the glass sphere of radius 6 cm and refractive index 1.5. The distance of the virtual image from the surface.

$$R = -R = -6 \text{ cm}$$

$$\mu_2 = 1$$

$$U = -R = -6 \text{ cm} \quad \mu_1 = \frac{3}{2}$$

$$V = ?$$



$$\frac{\mu_2}{V} - \frac{\mu_1}{U} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{1}{V} - \frac{3/2}{-6} = \frac{1/2}{+6}$$

$$\frac{1}{V} + \frac{3}{12} = \frac{1}{12}$$

$$\frac{1}{V} = \frac{1}{12} - \frac{3}{12} \Rightarrow \frac{1}{V} = -\frac{2}{12}$$

$$\boxed{V = -6 \text{ cm}}$$

Q4) A cylindrical glass rod refractive index 1.5 & radius 5 cm. An object height 0.5 mm and at a distance 20 cm. Find position of the ~~object~~ image & height.

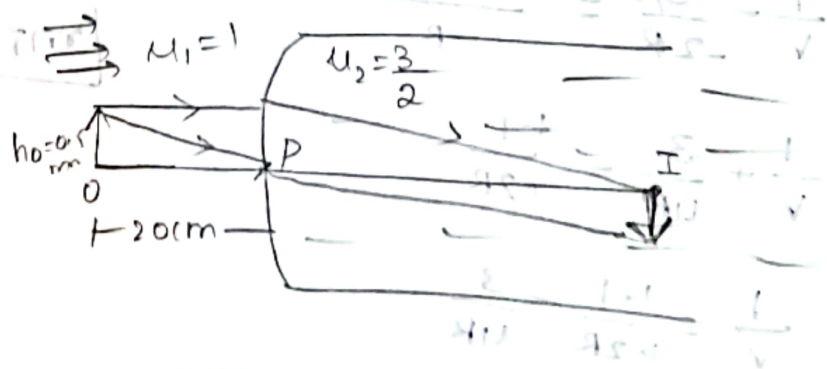
$$U = -20 \text{ cm}$$

$$R = +5 \text{ cm}$$

$$V = ?$$

$$\mu_1 = 1$$

$$\mu_2 = 3/2$$



$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{3}{2v} - \frac{1}{-20} = \frac{1.5 - 1}{5}$$

$$\frac{3}{2v} + \frac{1}{20} = \frac{1}{10}$$

$$\frac{3}{2v} = \frac{1}{10} - \frac{1}{20}$$

$$\frac{3}{2v} = \frac{2-1}{20}$$

$$\frac{3}{2v} = \frac{1}{20}$$

$$\frac{v}{3} = 10 \Rightarrow v = 30 \text{ cm}$$

$$m = \frac{h_i}{h_o} = \frac{\mu_1}{\mu_2} \left(\frac{v}{u} \right)$$

$$\frac{h_i}{0.5 \text{ mm}} = \frac{1}{3/2} \left(\frac{30}{-20} \right)$$

$$\frac{h_i}{0.5 \text{ mm}} = \frac{2}{3} \times \frac{3}{-2}$$

$$\frac{h_i}{0.5 \text{ mm}} = -1$$

$$h_i = -0.5 \text{ mm}$$

★

Ex. for auto collimation

Q5) A spherical curved surface of refractive index 1.5 & radius of curvature 10cm. The length of the cylinder 130cm. The other surface coated with silver of focal length 20cm. Find the position of the object, image is formed by itself.

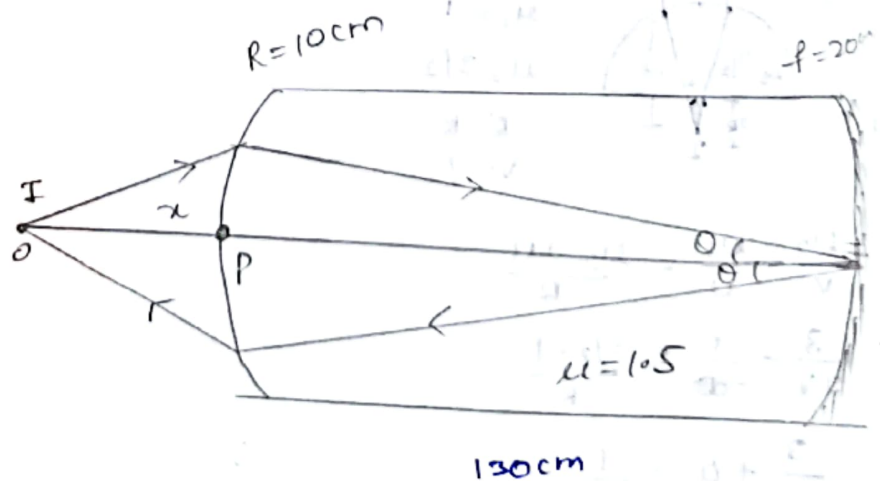
$$v = +130 \text{ cm}$$

$$R = 10 \text{ cm}$$

$$u = -x$$

$$\mu_2 = 1.5$$

$$\mu_1 = 1$$



$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

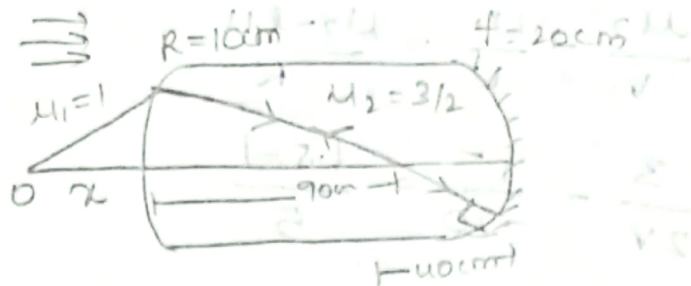
$$\frac{3}{2 \times 180} - \frac{1}{-x} = \frac{1.5 - 1}{10}$$

$$\frac{3}{260} + \frac{1}{x} = \frac{1}{20}$$

$$\frac{1}{x} = \frac{1}{20} - \frac{3}{260}$$

$$\frac{1}{x} = \frac{13 - 3}{260} = \frac{10}{260}$$

$$\boxed{x = 26 \text{ cm}}$$



$$v = 90 \text{ cm}; u = -x; \mu_2 = \frac{3}{2}$$

$$\mu_1 = 1; R = 10 \text{ cm}$$

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{3}{180} + \frac{1}{x} = \frac{1}{20} \Rightarrow \frac{1}{x} = \frac{1}{30}$$

$$\boxed{x = 30 \text{ cm}}$$

* Note: when object is placed at the centre.

Image also formed at the centre only.

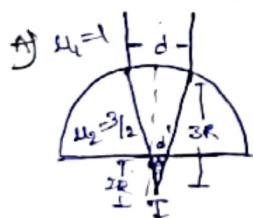
~~(Concave lens produce virtual image & diminished im)~~

Module

P: 107

Q: 39

39) A beam of diameter 'd' is incident on glass hemisphere of radius 'r'. Find the diameter of the beam at the base of the hemisphere.



$$u = -\infty$$

$$\mu_1 = 1$$

$$\mu_2 = 3/2$$

$$R = R$$

$$v = ?$$

$$\frac{d'}{2R} = \frac{d}{3R}$$

$$3d' = 2d$$

$$\boxed{d' = \frac{2}{3}d}$$

from the plane surface
distance = 2R.

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{3}{2v} - \frac{1}{-\infty} = \frac{3/2 - 1}{R}$$

$$\frac{3}{2v} + 0 = \frac{1}{2R}$$

$$\boxed{v = 3R}$$

24/04/2024 :-
(Wed) :-

* LENS *

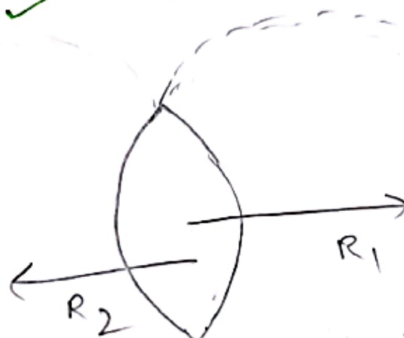
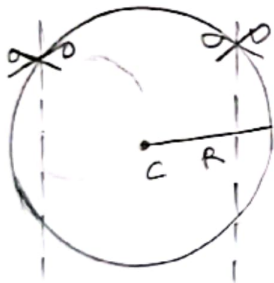
> A solid glass sphere cut into two pieces & join together is called Lens.

> If any refracting surface has at least one curved surface is called Lens. Lens are two types :-

- ① Convex lens
- ② Concave lens.

* Convex lens *

> A small portion/part removed from the solid sphere of radius R and joined together is called convex lens. ✓



* Types of convex lens :-

(i) Bi-convex lens :-

$$R_1 \neq R_2$$



(iii) Plano-convex lens :-



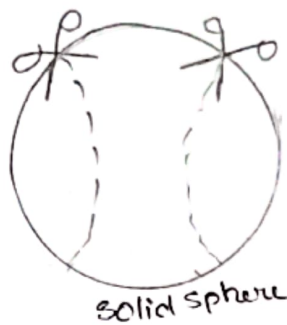
(ii) Equi-convex lens :-

$$R_1 = R_2$$

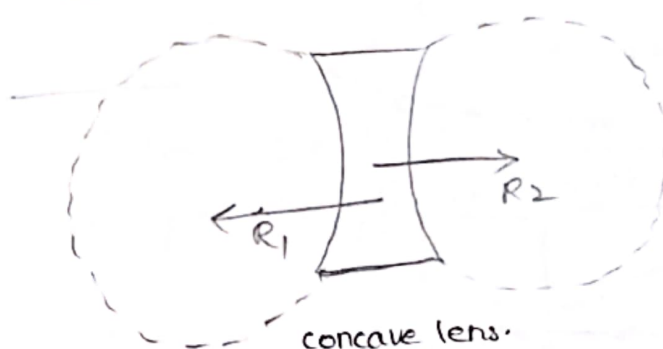


* Concave lens *

Q.1) A small portion removed from the solid sphere of radius R as show in figure:



concave lens.



* Type of concave lens :-

(i) Bi-concave lens :-



$$R_1 \neq R_2$$

(ii) Equi-concave lens :-



$$R_1 = R_2$$

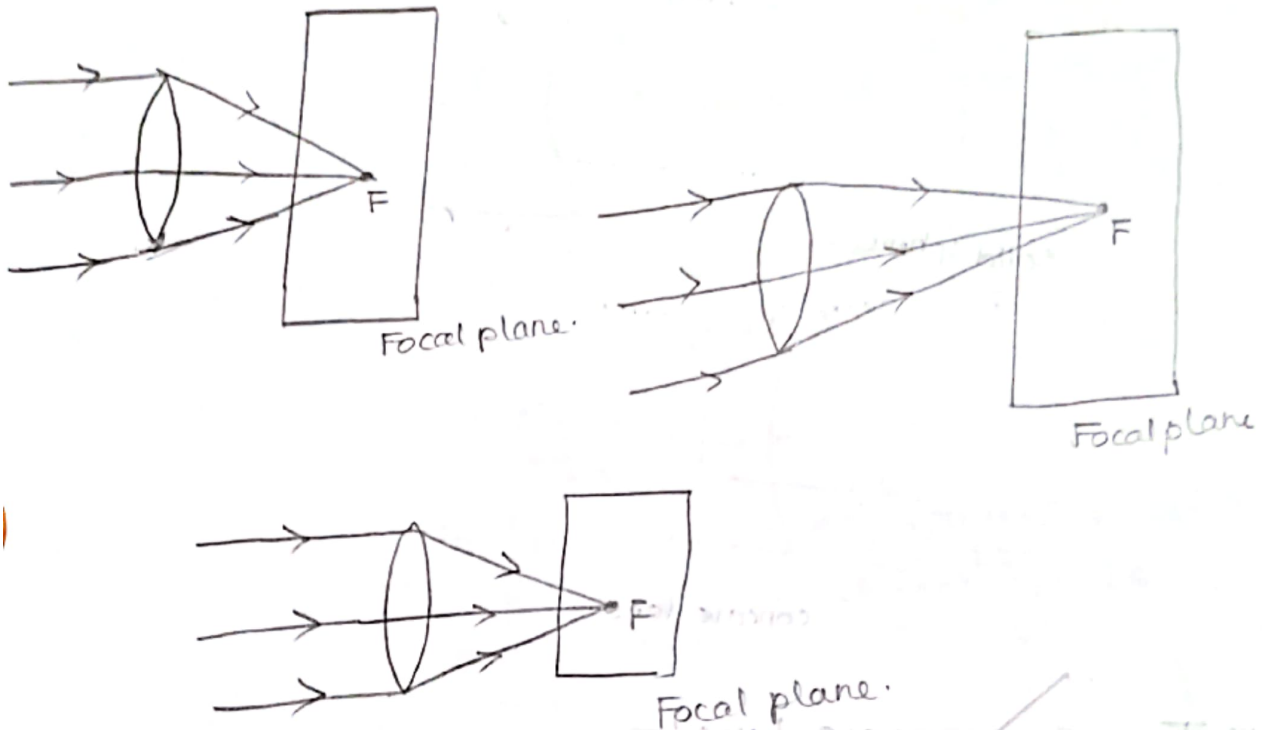
(iii) plano-concave lens :-



$$R_1 = \infty$$

* Focal Plane :-

> A plane which is constructed with focal length of the lens is called Focal plane. As show in figure :

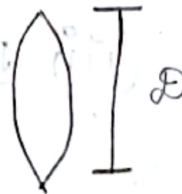


* Aperture (D) :-

> The diameter of the lens which allows light rays through it is called Aperture (D)

★ The intensity of the light rays $\propto$ square of the Aperture.

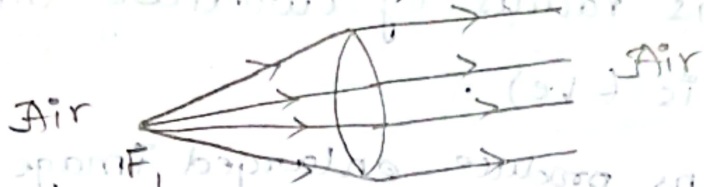
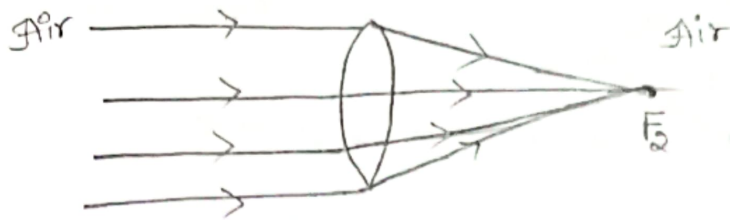
$$I \propto D^2$$



* Nature of the Convex lens :-

> When parallel rays incident on the convex lens it form the image at principle focus.

> When object placed at principle focus image formed at infinite distance as show in figure.



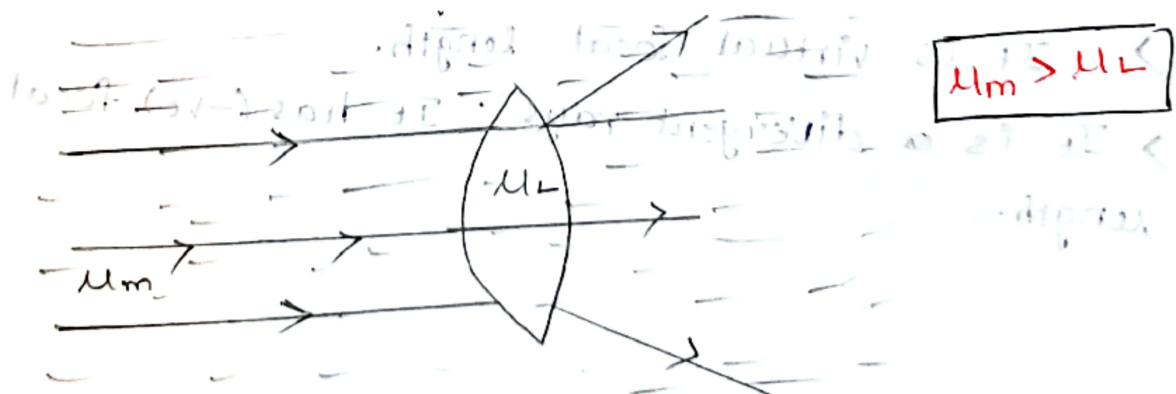
> convex lens produce convergent rays.

> It has positive focal length.
(+ve)

** It produce real image and virtual image for real object. *

** If refractive index of the medium > refractive index of the lens the nature of the lens changes. ~~The convex~~

* The convex lens act as concave lens:-



It act as a concave lens.

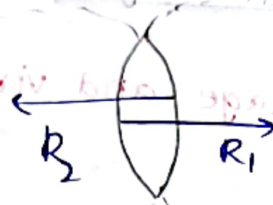
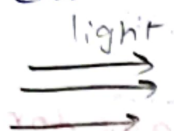
$$1/m < 1/f$$



same nature (convex).

> In convex lens radius of curvature (R_1) is (+ve) and R_2 is (-ve).

> The convex lens produce enlarged image and diminished image.



$$R_1 = +ve$$

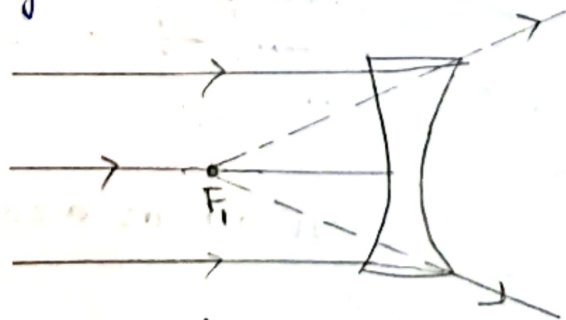
$$R_2 = -ve$$

* Nature of Concave lens:-

> When parallel rays incident on the concave lens it form the image at the principal focus.

> It is virtual focal length.

> It is a divergent rays. It has (-ve) focal length.



> concave lens produce virtual image & diminished image.

25/04/2024 (Thu):

> It produce erect image.

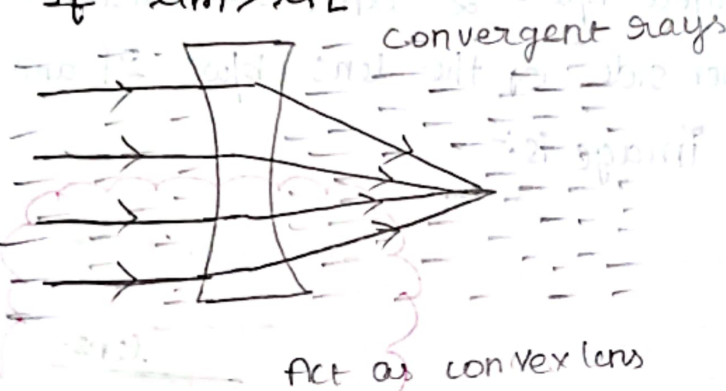
> In concave lens R_1 taken as (-ve) and R_2 taken as (+ve).

$R_1 = -ve$
 $R_2 = +ve$

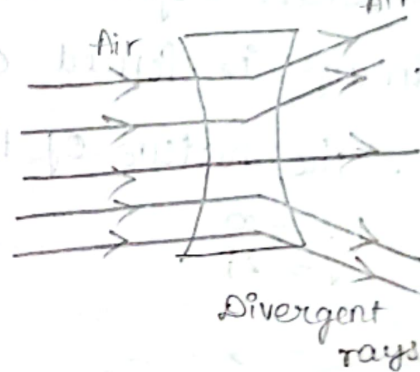


* If refractive index of the medium > refractive index of the lens. The nature of the concave lens changes. It act as a convex lens.

If $\mu_m > \mu_L$

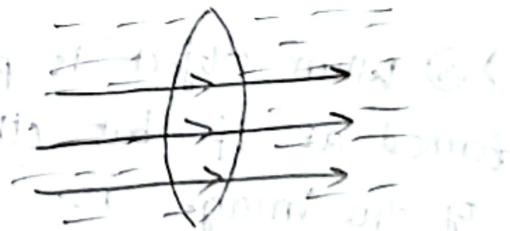
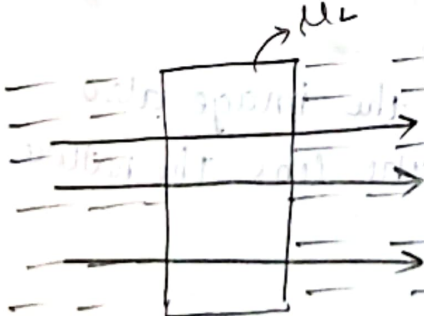


If $\mu_m < \mu_L$



> Then refractive index of the medium is equal to refractive index of the lens, $\mu_m = \mu_L$. Then it acts as a transparent glass sheet.
(No deviation, No reflection)

$\mu_m = \mu_L$

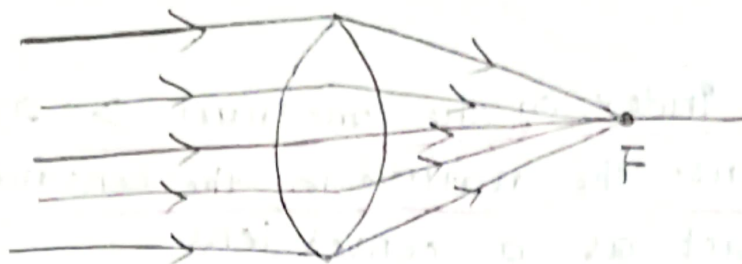


* Image formation in lenses:- (convex lens)

> ① When object arranged at ∞ distance it forms the image at Principal focus. (F) ✓

$$U = -\infty$$

$$V = f$$

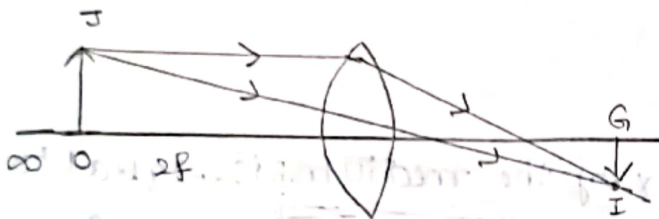


- * Real image
- * Inverted image
- * point size
- * $m < -1$

> ② When object arranged b/w ∞ and $2f$ distance image is formed other side of the lens b/w $2f$ and f . The nature of the image is:-

$$U = -\infty$$

$$V = 2f$$



- * Real image
- * Inverted image
- * Diminished
- * $m < -1$

In mirrors:-

$$2f = C$$

In ~~mirrors~~ lens:-

$$2f \neq C$$

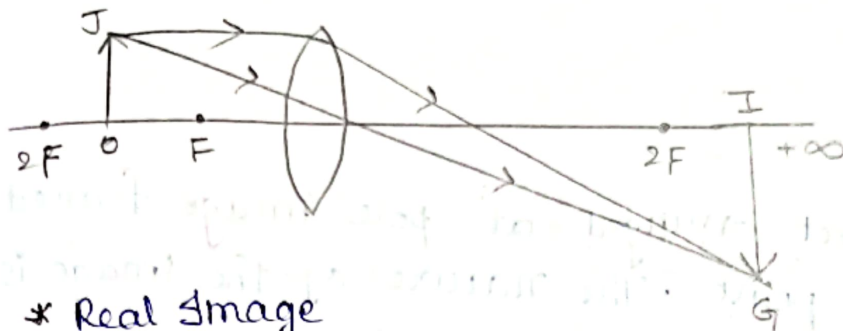
> ③ When object is placed at $2f$ the image also formed at $2f$ but other side of the lens the nature of the image is.

$$U = -2f ; V = 2f$$



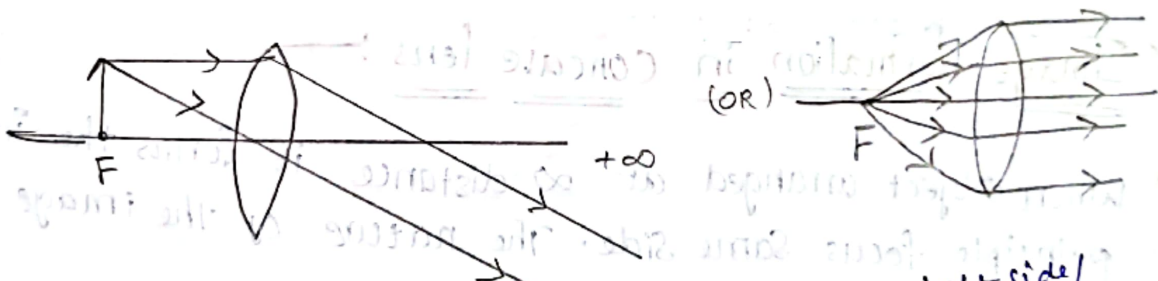
- * Real image
- * Inverted image
- * Same size ($h_i = h_o$)
- * $m = -1$

> ④ When object arranged b/w $2f$ and f image is formed b/w $2f$ and ∞ other side of the lens. The nature of the image is:-



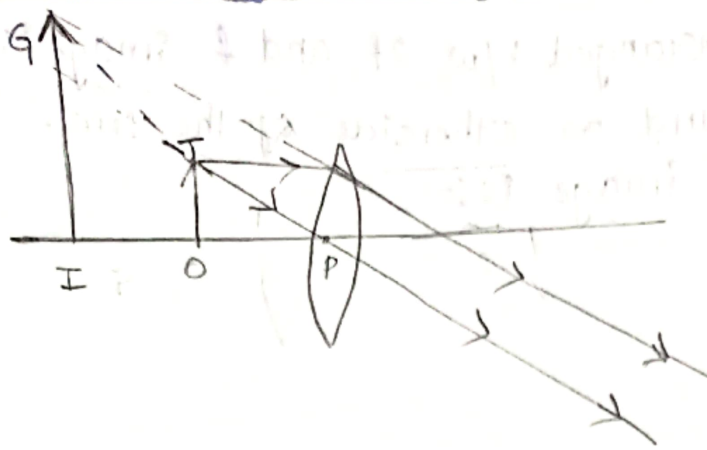
- * Real Image
- * Enlarged image
- * Inverted image
- * $m > -1$

> ⑤ When object is placed at principle focus then the image is formed at $+\infty$ distance but other side of the lens the nature of the image is:-



- * Real image (right side) (OR) virtual (at left side)
- * Inverted image (at right side) (OR) erected (at left side)
- * Enlarged or magnified
- * $m > -1$ (right side) (OR) $m > 1$ (at left side)

> ⑥ When object is placed b/w f and pole then the image is formed b/w $2f$ and f same side of the lens the nature of the image is:-



- * Virtual image.
- * Erect image.
- * Magnified image.
- * $m > 1$

> ⑦ When object arranged at pole image formed at the same point. The nature of the image is

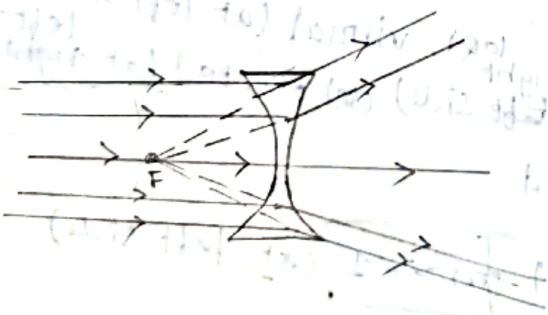


- * Virtual image.
- * Erect image.
- * Same size.
- * $m = 1$

* Note :- At the pole, the lens act as a plane mirror

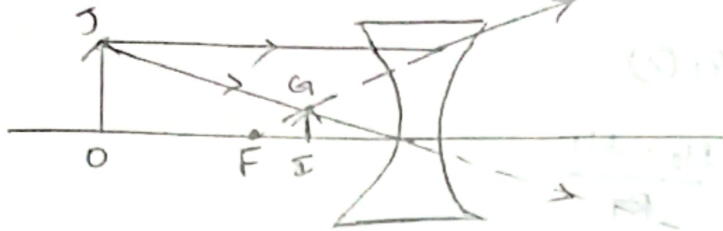
* Image formation in Concave lens :-

> ① When object arranged at ∞ distance it forms the image at principle focus same side. The nature of the image is



- * virtual image
- * Erected image
- * Diminished image
- * $m < 1$

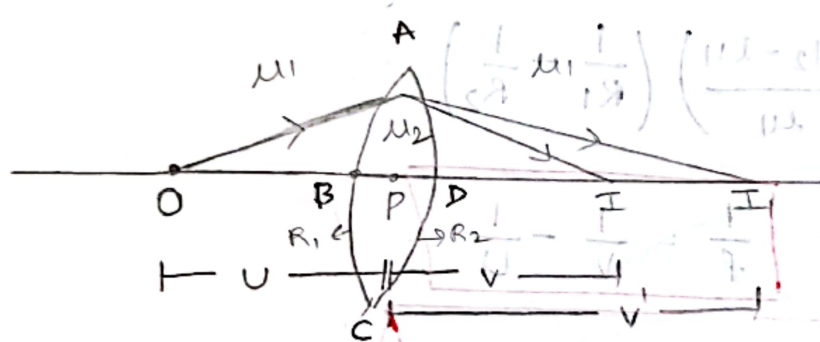
> ② When object arranged b/w ∞ to pole it forms the image virtual, erect and diminished image only.



$$m < +1$$

★★ Lens maker formula:- (vvi)

A spherical lens of refractive index μ . The radius of curvatures R_1 and R_2 arranged as show in figure. The effective focal length of the lens is f .



For curved surface (ABC) $\left(1 - \frac{\mu_2}{\mu_1}\right) = \frac{1}{R_1}$

$$\frac{\mu_2}{v'} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} \quad \text{--- (1)}$$

For curved surface ADC

$$\frac{\mu_1}{v} - \frac{\mu_2}{v'} = \frac{\mu_1 - \mu_2}{R_2}$$

$$\frac{\mu_1}{v} - \frac{\mu_2}{v'} = -\frac{(\mu_2 - \mu_1)}{R_2} \quad \text{--- (2)}$$

adding eqn (1) and (2)

$$\frac{\mu_2}{v'} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} \left(1 - \frac{v}{v'}\right) = \frac{1}{f}$$

showing derivation

Adding eqn ① & ②

$$\frac{\cancel{\mu_2}}{v'} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1}$$

$$+ \frac{\mu_1}{v} - \frac{\cancel{\mu_2}}{v'} = \frac{\mu_2 - \mu_1}{-R_2}$$

$$\frac{\mu_1}{v} - \frac{\mu_1}{u} = \mu_2 - \mu_1 \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\mu_1 \left[\frac{1}{v} - \frac{1}{u} \right] = \mu_2 - \mu_1 \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{\mu_2 - \mu_1}{\mu_1} \right) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

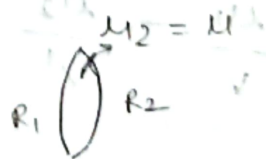
lens formula

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1 \right) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$



(OR) $\mu_1 = 1$



$$\frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

(VVI)

↳ lens maker's formula.

* Note:-

lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\textcircled{1} \quad \frac{1}{v} = \frac{1}{f} + \frac{1}{u}$$

$$\frac{1}{v} = \frac{u+f}{uf}$$

$$v = \frac{uf}{u+f}$$

*

$$\textcircled{2} \quad \frac{1}{u} = \frac{1}{f} - \frac{1}{v}$$

$$\frac{1}{u} = \frac{f-v}{vf}$$

$$u = \frac{vf}{f-v}$$

*

$$\textcircled{3} \quad \frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

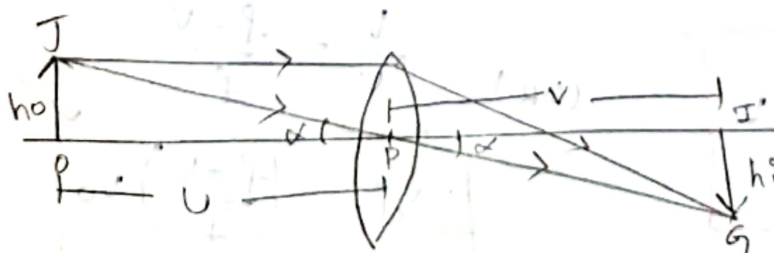
$$\frac{1}{f} = \frac{u-v}{uv}$$

$$f = \frac{uv}{u-v}$$

* Magnification *

> Transverse Magnification:-

The ratio of size of the image to size of the object is called Transverse magnification.



$$m_T = \frac{h_i}{h_o}$$

$$m_T = \frac{v}{u}$$

$$\tan \alpha = \frac{h_o}{u} = \frac{h_i}{v}$$

$$\Rightarrow \boxed{\frac{h_i}{h_o} = \frac{v}{u}}$$

In mirrors:-

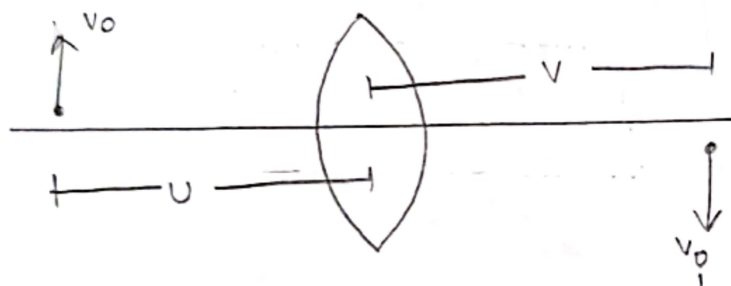
$$m = \left(\frac{v}{u}\right)$$

In lens:-

$$m = \frac{v}{u}$$

App - (1)

> An object moving with velocity v_o $\perp$ er to the principle axis at a distance u it forms the image at a distance v . The speed of the image is



$$\frac{h_i}{h_o} = \frac{v}{u}$$

$$h_i = \left(\frac{v}{u}\right) h_o$$

$$\frac{dh_i}{dt} = \left(\frac{v}{u}\right) \frac{dh_o}{dt}$$

$$\boxed{v_i = \left(\frac{v}{u}\right) v_o} \quad (\text{OR}) \quad \boxed{v_i = m v_o}$$

$$\frac{v}{u} = \frac{f}{f+u}$$

$$\boxed{v_i = \left(\frac{f}{f+u}\right) v_o}$$

$$(\text{OR}) \quad \frac{v}{u} = \frac{f-v}{f}$$

$$\boxed{v_i = \left(\frac{f-v}{f}\right) v_o} \quad \checkmark$$

26/04/2024 (Fri) :-

* Longitudinal Magnification :- (m_L)

> An object arranged at a distance u , it forms the image at a distance v from the pole. The longitudinal magnification is:-

$$\text{WKT } \frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} - \frac{1}{u} = f^{-1}$$

$$(-1) v^{-2} \cdot dv + (-1) u^{-2} du = 0 \quad \checkmark \text{ difference}$$

$$-\frac{dv}{v^2} + \frac{du}{u^2} = 0$$

$$\frac{dv}{v^2} = \frac{du}{u^2}$$

$$\frac{dv}{du} = \left(\frac{v}{u}\right)^2 \Rightarrow dv = \left(\frac{v}{u}\right)^2 du$$

$$m_L = \left(\frac{v}{u}\right)^2$$

→ App - ①

An object moves towards lens with velocity v_0 at position u . It forms the image at a distance v . The speed of the image w.r. to pole

Longitudinal magnification

$$\frac{dv}{du} = \left(\frac{v}{u}\right)^2$$

$$dv = \left(\frac{v}{u}\right)^2 du$$

Differentiate w.r. to time.

$$\frac{dv}{dt} = \left(\frac{v}{u}\right)^2 \frac{du}{dt}$$

$$v_i = \left(\frac{v}{u}\right)^2 v_0 \quad \text{(or)} \quad v_i = m^2 v_0$$

In terms of focal length:-

$$\frac{1}{v} = \frac{1}{u} + \frac{1}{f} \rightarrow (1)$$

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

By (1) $\Rightarrow \frac{1}{v} = \frac{u+f}{uf}$

$$v = \frac{uf}{u+f}$$

$$\boxed{\frac{v}{u} = \frac{f}{f+u}}$$

Then,

$$v_i = \left(\frac{v}{u}\right)^2 v_o$$

$$\boxed{v_i = \left(\frac{f}{f+u}\right)^2 v_o}$$

(OR)

$$\boxed{v_i = \left(\frac{f-u}{f}\right)^2 v_o}$$

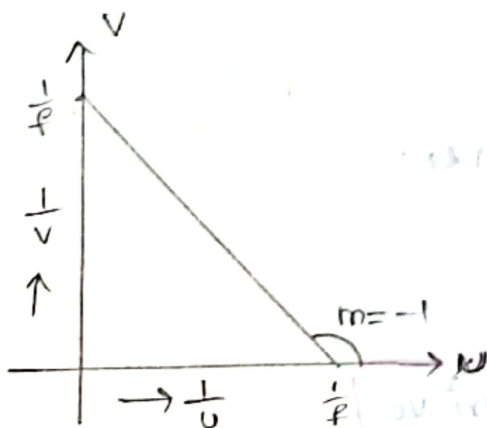
↳ Derived in last class.

* GRAPHS :-

> A graph drawn b/w $\frac{1}{v}$ and $\frac{1}{u}$. The nature of the graph is.

• convex lens.

→ For real image:-



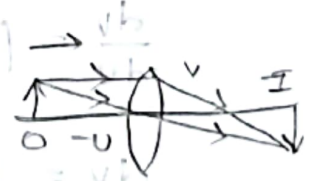
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} = \frac{1}{(-u)} + \frac{1}{f}$$

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} = (-1)\left(\frac{1}{u}\right) + \frac{1}{f}$$

$$y = mx + c$$

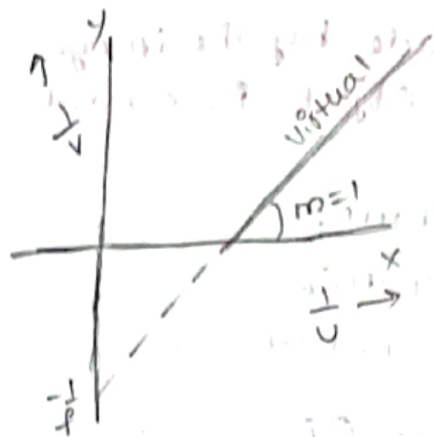


$u = -ve$

$v = +ve$

→ For virtual image in convex lens :-

$$u = -u ; v = -v ; f = +f$$



$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$-\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

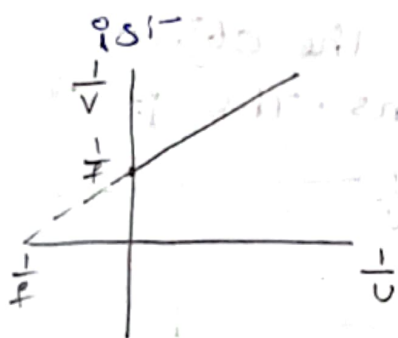
$$y = mx + c$$

$$\frac{1}{v} = (1) \left(\frac{1}{u} \right) + \left(-\frac{1}{f} \right)$$

26/4/24

• Concave lens :-

A graph drawn b/w $\frac{1}{v}$ and $\frac{1}{u}$ for concave lens.



$$u = -u$$

$$v = -v$$

$$f = -f$$

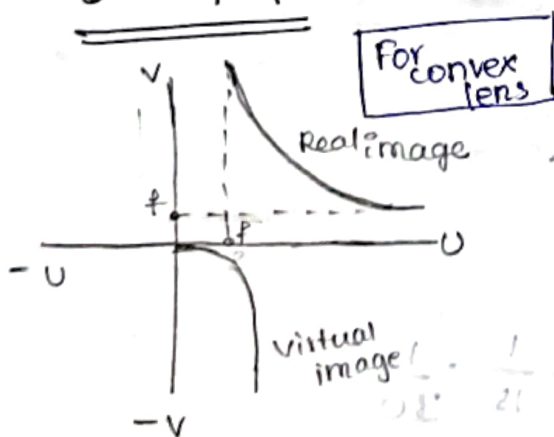
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{+v} - \frac{1}{+u} = \frac{1}{+f}$$

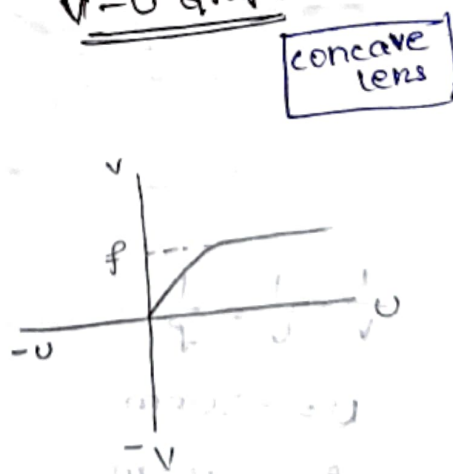
$$\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$$

$$y = (1)(m) + c$$

u-v Graph :-

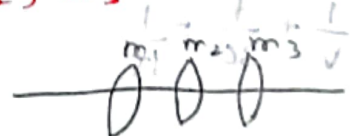


v-u Graph :-



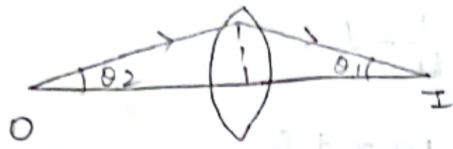
* Note : ① When two or more lenses arranged along the common axis. The effective magnification for each of magnification $m_1, m_2, m_3, \dots$

$$m = m_1 \times m_2 \times m_3 \times \dots$$



② Angular magnification (m):-

The ratio of tangent angle made by the image to tangent angle made by the object is called Angular magnification.



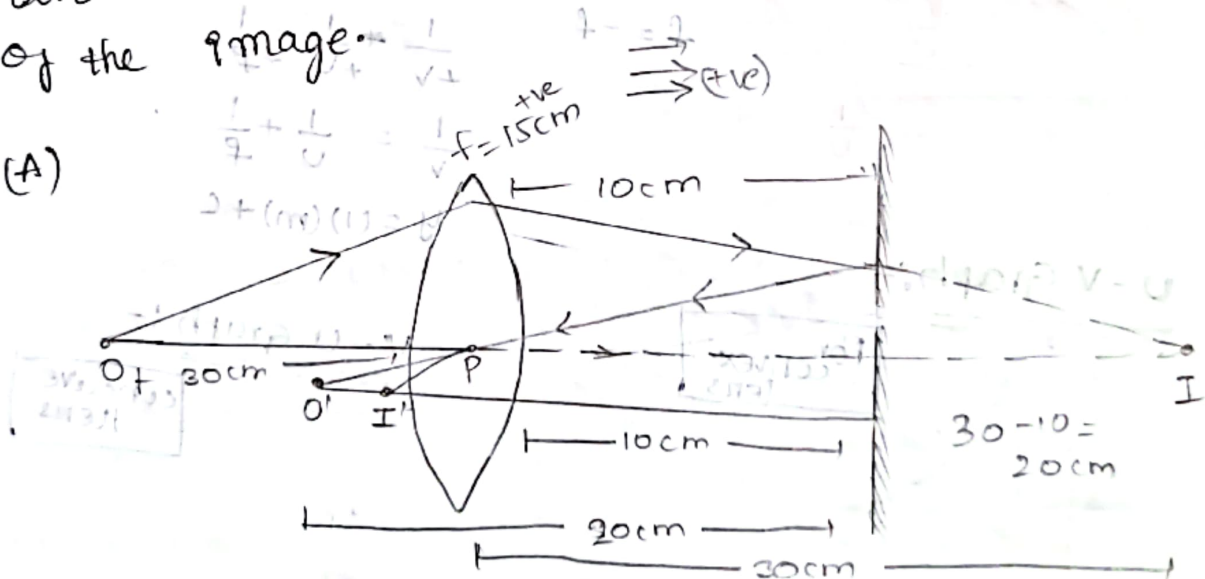
$$m = \frac{\tan \theta_i}{\tan \theta_o}$$

for small angles

$$m = \frac{\theta_i}{\theta_o} \quad \checkmark$$

> (Q) A biconvex lens of focal length 15cm. The distance b/w lens and mirror is 10cm. Arranged as show in figure. The object distance 30cm from the lens. The position of the image.

(A)



$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$u = -30\text{cm}$$

$$f = +15\text{cm}$$

$$\frac{1}{v} = \frac{1}{15} - \frac{1}{30}$$

$$\frac{1}{v} = \frac{2-1}{30}$$

$$v = 30\text{cm}$$

$$\frac{1}{v} - \frac{1}{-30} = \frac{1}{15}$$

$$\frac{1}{v} + \frac{1}{30} = \frac{1}{15}$$

$$u = +10 \text{ cm}$$

$$f = +15 \text{ cm}$$

$$v = ?$$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} - \frac{1}{10} = \frac{1}{15}$$

$$\frac{1}{v} = \frac{1}{15} + \frac{1}{10}$$

$$\Rightarrow \frac{1}{v} = \frac{10+15}{150}$$

$$\frac{1}{v} = \frac{3+2}{150}$$

$$\frac{1}{v} = \frac{5}{150}$$

$$\frac{1}{v} = \frac{1}{30}$$

$$v = 30 \text{ cm}$$

$$\frac{1}{v} = \frac{2+3}{30}$$

$$v = \frac{30}{5}$$

$$v = 6 \text{ cm}$$

Final image from lens = 6 cm

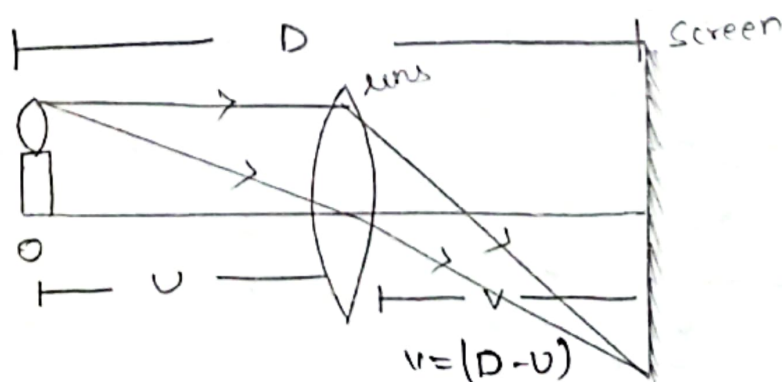
Final image from mirror = 16 cm

27/01/2020 : (Sat):

(11)

* Lens Displacement Method :-

> Lens Displacement method is used to calculate focal length of the lens. A convex lens and screen, object arranged along the common axis. The distance b/w object and screen is D , arranged as shown in figure.



$$u = -u$$

$$v = + (D-u)$$

lens formula:-

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{D-u} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{u + D - u}{u(D-u)} = \frac{1}{f}$$

$$\frac{D}{u(D-u)} = \frac{1}{f}$$

$$uD - u^2 = Df$$

$$u^2 - Du + Df = 0$$

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$u = \frac{D \pm \sqrt{D^2 - 4(D)f}}{2(1)}$$

$$u = \frac{D \pm \sqrt{D(D-4f)}}{2}$$

case-(1):

$D < 4f$ It is imaginary number. No image is possible.

Case-(2) :-

$$D = 4f$$

$$u = \frac{D}{2} = \frac{4f}{2} = 2f$$

only one image possible.

Case-(3) :-

$$D > 4f$$

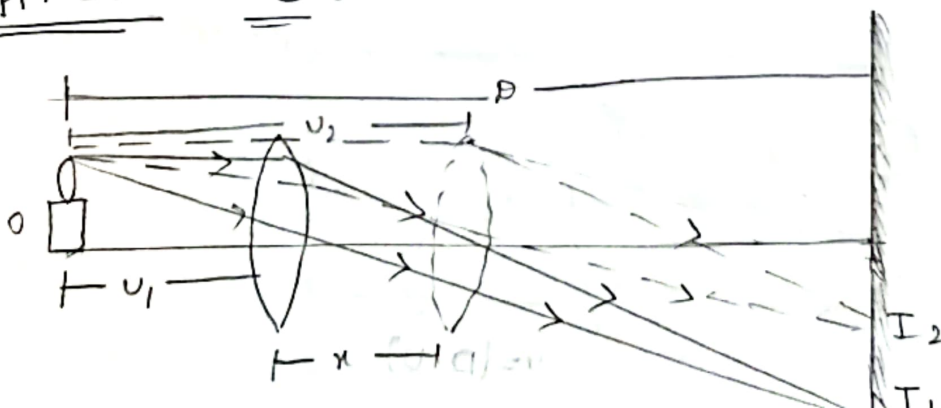
Two images are possible.

$$u_1 = \frac{D + \sqrt{D(D-4f)}}{2}$$

$$u_2 = \frac{D - \sqrt{D(D-4f)}}{2}$$

* Note: In lens displacement method object and image distance should be greater than $4f$

> Application — (1) :-



$$u_2 - u_1 = x \quad \text{--- (1)}$$

$$u_2 + u_1 = D \quad \text{--- (2)}$$

$$(1) + (2) \Rightarrow 2u_2 = x + D$$

$$u_2 = \frac{D+x}{2}$$

$$u_1 = \frac{D-x}{2}$$

$$\begin{aligned} v_2 &= u_1 \\ v_1 &= u_2 \end{aligned}$$

$$\begin{aligned} v_1 &= D - u_1 \\ v_1 &= D - \left(\frac{D-x}{2} \right) \\ v_1 &= \frac{2D - D + x}{2} \end{aligned}$$

$$v_1 = \frac{D+x}{2}$$

$$v_1 = \frac{D+x}{2} = u_2$$

→ case - (1) :-

$$u = -u_1 = -\left(\frac{D-x}{2} \right)$$

$$v = v_1 = \left(\frac{D+x}{2} \right)$$

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

$$\frac{1}{f} = \frac{2}{D+x} + \frac{2}{D-x} = \frac{4D}{D^2 - x^2}$$

$$f = \frac{D^2 - x^2}{4D}$$

> App - (2) :-

$$m_1 = \frac{v}{u} = \frac{\frac{D+x}{2}}{\frac{D-x}{2}} = \frac{D+x}{D-x}$$

$$m_1 = \frac{D+x}{D-x}$$

$$m_2 = \frac{v_2}{u_2} = \left(\frac{D-x}{2} \right) \left(\frac{2}{D+x} \right)$$

$$m_2 = \frac{D-x}{D+x} *$$

$$* m_1 m_2 = \left(\frac{D+x}{D-x} \right) \left(\frac{D-x}{D+x} \right)$$

$$m_1 m_2 = 1$$

→ App - ③ :-

$$m_1 - m_2 = \frac{D+x}{D-x} - \left(\frac{D-x}{D+x} \right)$$

$$= \frac{(D+x)^2 - (D-x)^2}{D^2 - x^2}$$

$$m_1 - m_2 = \frac{4Dx}{D^2 - x^2} *$$

$$f = \frac{D^2 - x^2}{4D}$$

$$f = \frac{x}{m_1 - m_2}$$

$$m_1 - m_2 = \frac{x}{f}$$

* Power of lens :-

> The ability of the lens to bend the light ray is called Power (OR)

> Power of lens defined as the reciprocal of the focal length is called Power

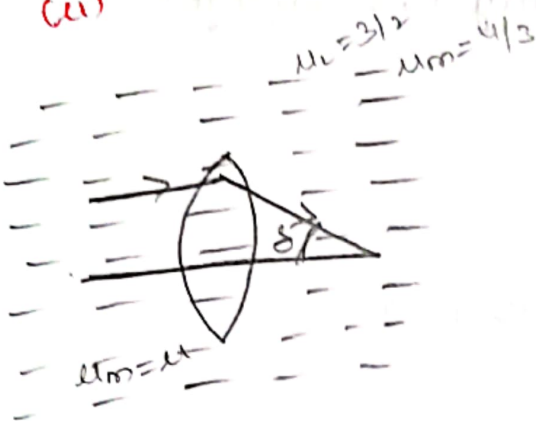


$$\tan \delta = \frac{1}{f} \text{ for small angles}$$

$$\delta = \frac{1}{f} \Rightarrow \boxed{P = \frac{1}{f}} *$$

* Note :-

When lens is arranged in medium of refractive index. The power of lens is:



$$\boxed{P = \frac{\mu_{\text{medium}}}{f}} *$$

Unit :- $\frac{1}{m}$ (or) Dioptre (or) D

$$\boxed{\text{power (P)} = \frac{1}{f \text{ (in m)}}} ; P = \frac{1}{f \text{ (in cm)}} = \frac{100}{f \text{ (in m)}} = \frac{100}{f}$$

$$\boxed{P = \frac{100}{f} \text{ D}}$$

- > Convex lens (or) convergent rays have (+ve) power
- > Concave lens (or) divergent rays have (-ve) power.

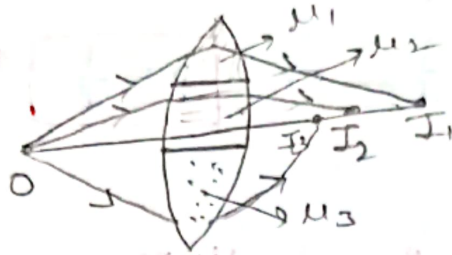
* Number of images due to lens :-

> We know;

$$\frac{1}{f} \propto (\mu - 1)$$

> ① When materials are arranged || to principle axis then n different types of materials produce 'n' number of images as show in figure.

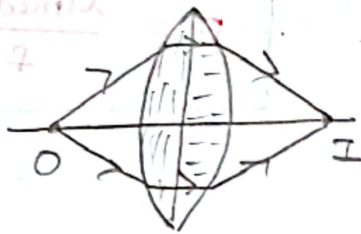
• Ex ①



3 images.

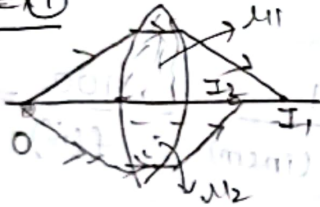
> ② When materials are ⊥ to the principle axis then it produced only one image.

Ex ①



1 image.

• Ex ①



2 images.

* Cutting of lens :-

(pacc bit)
in mains.

> The size of the aperture is directly proportional to intensity of light

$$\text{Size of aperture} \propto I$$

> The thickness of the lens $\propto$ power

$$\text{Thickness} \propto P$$

> Focal length $\propto \frac{1}{\text{power}}$

$$P \propto \frac{1}{f}$$

➤ From the principle axis upper part produce convergent rays but lower part bend the light rays opposite to the upper part of the lens

→ Application ①:-

➤ A convex lens of focal length f , power P , intensity I . It is divided into 2 equal parts along the principle axis. Find new power, focal length & intensity for each part:-

Ex ①

$$P_1 = P$$

$$f_1 = f$$

$$I_1 = I$$



$$P_2 = P$$

$$f_2 = f$$

$$I_2 = \frac{I}{2}$$

Ex ②

$$P_1 = P$$

$$f_1 = f$$

$$I_1 = I$$



$$P_2 = P/2$$

$$I_2 = I$$

$$f_2 = 2f$$

$$P_2 = P/2$$

$$\frac{1}{f_2} = \frac{1/4}{2}$$

$$\frac{1}{f_2} = \frac{1}{2f}$$

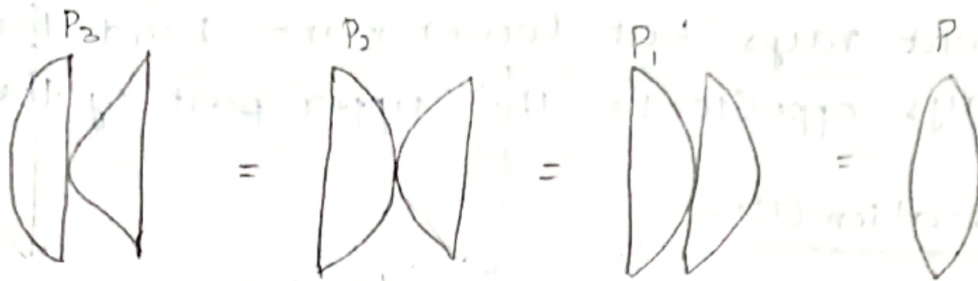
$$f_2 = 2f$$

↪ Ex ③

A convex lens divided into two pieces $\perp$ er to principle axis. Initial power P , focal length f & intensity I . Find each piece of the new power, focal length and intensity.

Ex ③:-

A convex lens divide into two equal pieces $\perp$ er to the principle axis and arranged as show in figure. Focal length, power and intensity remains constant.



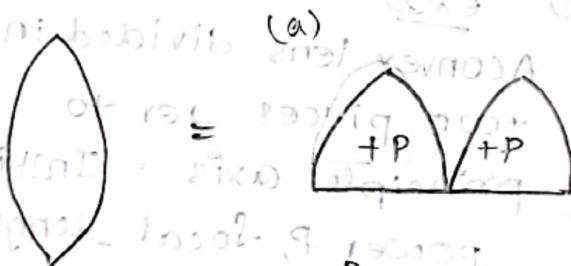
$$P_1 = P_2 = P_3 = P$$

$$I_1 = I_2 = I_3 = I$$

$$f_1 = f_2 = f_3 = f$$

Ex(4)

A convex lens divides two equal pieces along the principle axis arranged in same order and reverse order as show in figure. Find new power, focal length and intensity.



(a)

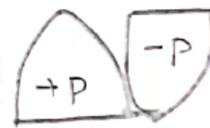
$$P_2 = 2P$$

$$\frac{1}{f_2} = \frac{2}{f}$$

$$f_2 = f/2$$

$$I_2 = I/2$$

(b)



$$P_3 = P - P = 0$$

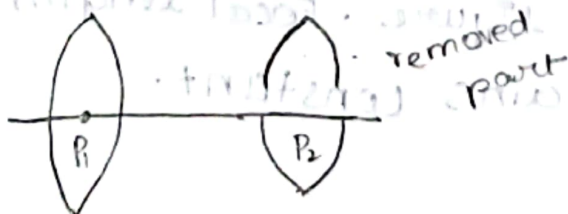
$$f_3 = \infty$$

$$I_3 = \frac{I}{2}$$

It act as plane sheet.

Ex(5)

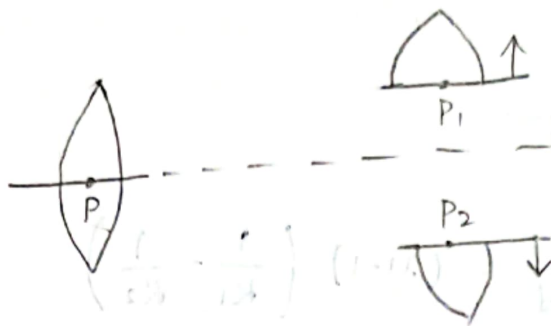
A convex lens middle portion removed without any disturbance as show in figure



Same principal axis
Same power
same focal length
One image

Ex(6):-

A convex lens middle portion removed and adjusted away from the each other. Each part of the piece act^{as} its own principle axis



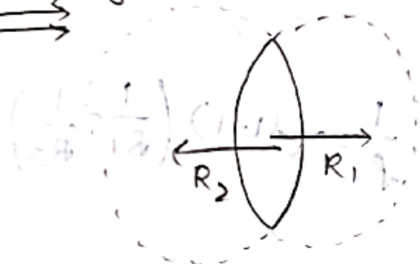
Two principal axis
Two images
Same power
Same focal length

⇒ APP-①

① Bi-convex-lens :- ✓

→ A biconvex lens each of radius r_1 and r_2 . The effective focal length.

⇒ light



$R_1 = +ve$
 $R_2 = -ve$

$$\frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$R_1 = +ve$; $R_2 = -ve$

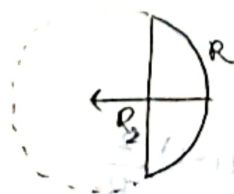
$$\frac{1}{f_{eff}} = (\mu - 1) \left(\frac{1}{R_1} + \frac{1}{R_2} \right)$$

for equi convex $R_1 = R_2 = R$

$$\frac{1}{f_{eff}} = (\mu - 1) \left(\frac{2}{R} \right)$$

⇒ App-② :-

② plano convex lens :-



$R_1 = \infty$
 $R_2 = -R$

$$\frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

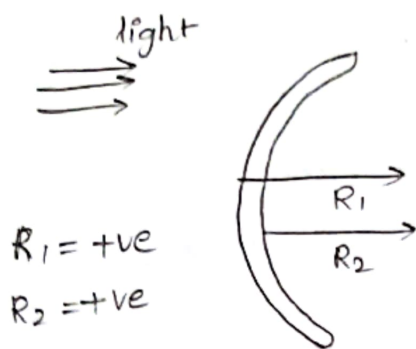
$R_1 = \infty$; $R_2 = -R$

$$\frac{1}{f_{eff}} = (\mu - 1) \left(\frac{1}{\infty} - \frac{1}{-R} \right)$$

$$\frac{1}{f_{\text{eff}}} = \frac{\mu - 1}{R}$$

⇒ App - ② :-

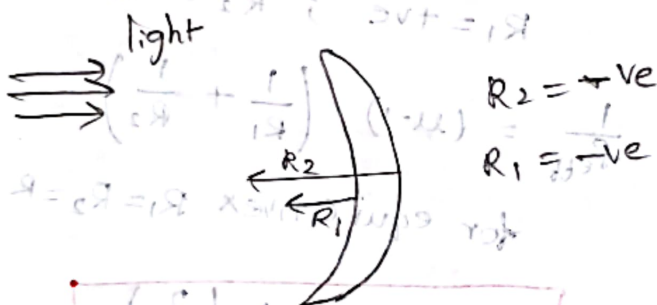
Convergent meniscus :-



$$\frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

⇒ App - ④ :-

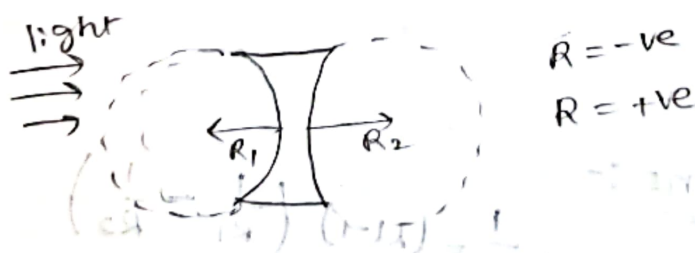
Divergent meniscus :-



$$\frac{1}{f} = -(\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

⇒ App ⑤ :-

Bi-concave lens :-



$$\frac{1}{f} = -(\mu - 1) \left(\frac{1}{R_1} + \frac{1}{R_2} \right)$$

For Equiconcave lens

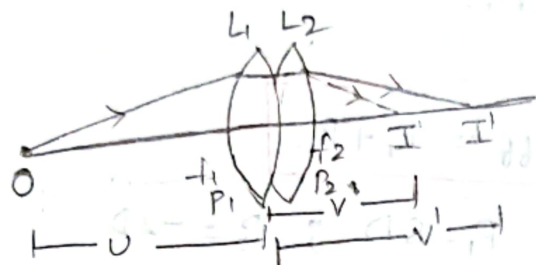
$$R_1 = R_2 = R = \frac{1}{\text{dist}}$$

$$\frac{1}{f} = -(\mu - 1) \frac{2}{R}$$

29/04/2024
(Mon)

Combination of lenses :-

> Two (or) more lenses arranged with common axis each of focal length $f_1, f_2, \dots$ and each of power $P_1, P_2, P_3, \dots$. The effective focal length and power P_s :-



For lens L_1 :-

$$U = U$$

$$V = V'$$

$$f = f_1$$

$$\frac{1}{V} - \frac{1}{U} = \frac{1}{f}$$

$$\frac{1}{V'} - \frac{1}{U} = \frac{1}{f_1} \quad \text{--- (1)}$$

$$\frac{1}{V'} - \frac{1}{U} = \frac{1}{f_1} \quad \text{--- (1)}$$

(1) + (2)

$$\frac{1}{V'} - \frac{1}{U} = \frac{1}{f_1}$$

$$\frac{1}{V} - \frac{1}{V'} = \frac{1}{f_2}$$

$$\frac{1}{V} - \frac{1}{U} = \frac{1}{f_1} + \frac{1}{f_2}$$

For lens L_2 :-

$$U = V'$$

$$V = V$$

$$f = f_2$$

$$\frac{1}{V} - \frac{1}{U} = \frac{1}{f}$$

$$\frac{1}{V} - \frac{1}{V'} = \frac{1}{f_2} \quad \text{--- (2)}$$

General formula

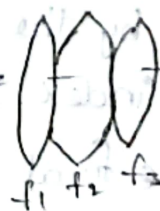
$$\frac{1}{f_{\text{eff}}} = \frac{1}{f_1} + \frac{1}{f_2} \quad *$$

$$P_{\text{eff}} = P_1 + P_2 \quad *$$

* NOTE: If 'n' no. of lenses each of focal length $f_1, f_2, f_3, \dots$ arranged at common axis as show in figure

$$P_{\text{eff}} = P_1 + P_2 + P_3 + \dots \quad *$$

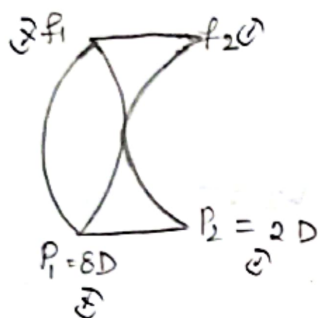
$$\frac{1}{f_{\text{eff}}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \dots \quad *$$



⇒ Applications :-

→ App - (1) :-

A convex lens of focal length f_1 & power P_1 .
A concave lens of focal length f_2 & power P_2
arranged as show in figure. Find effective focal length and power.



$$P_{\text{eff}} = P_1 + P_2$$

$$P_1 = 8D ; P_2 = -2D$$

$$P_{\text{eff}} = P_1 + P_2$$

$$= 8D - 2D = 6D \checkmark$$

$$P_{\text{eff}} = 6D$$

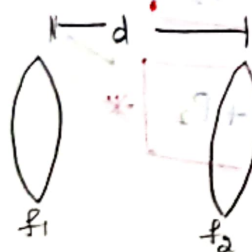
$$\frac{1}{f_{\text{eff}}} = \frac{6}{m}$$

$$f_{\text{eff}} = \frac{100 \text{ cm}}{6}$$

$$f_{\text{eff}} = 16.6 \text{ cm}$$

→ App - (2) :-

Two convex lens each of focal length f_1 & f_2 which are separated by the distance 'd'. Find effective focal length and effective power.

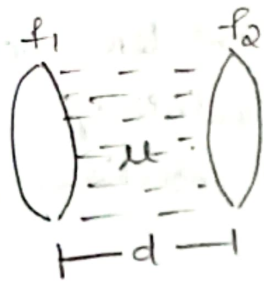


$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2} \checkmark$$

$$P = P_1 + P_2 - d P_1 P_2 \checkmark$$

→ App - (3) :-

Two lens each of focal length f_1 and f_2 which are separated by the distance 'd' and filled with liquid of refractive index 'u' arranged as show in figure. The effective focal length and power is :-

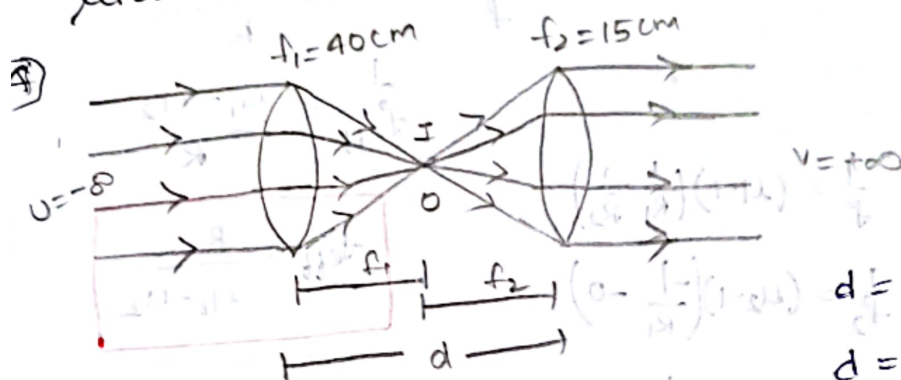


$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{d}{d f_1 f_2}$$

$$P = P_1 + P_2 = \frac{d}{d} P_1 P_2$$

previous. pacca (Q) in Mains :-

> (Q) Two convex lens each of focal length 40cm and 15cm arranged as show in figure. When parallel rays incident on the first lens emergent parallel rays from the second lens. The distance b/w the lens is :-

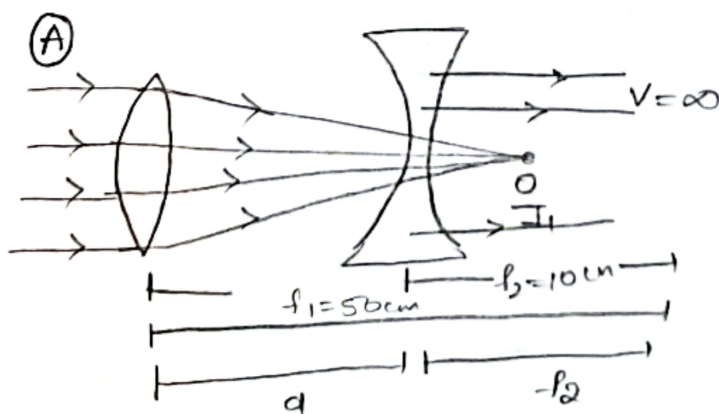


$$d = f_1 + f_2$$

$$d = 40 + 15$$

$$\boxed{d = 55\text{cm}}$$

> (Q) A convex lens of focal length 50cm. A concave lens of focal length 10cm. When parallel rays incident on first lens and parallel rays emergent from the second lens. The distance b/w the two lenses is :-



$$f_1 = d + f_2$$

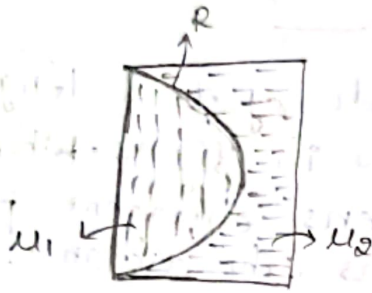
$$d = f_1 - f_2$$

$$d = 50 - 10$$

$$\boxed{d = 40\text{cm}}$$

> (Q) A plano convex lens and a plano concave lens each of refractive index μ_1 and μ_2 with same radius of curvature arranged as shown in figure. The effective focal length is:-

(A)



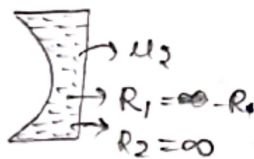
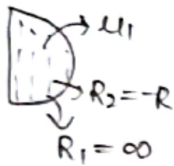
$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{1}{f} = \frac{\mu_1 - 1}{R} + \frac{\mu_2 - 1}{R}$$

$$\frac{1}{f} = \frac{\mu_1 - \mu_2}{R}$$

$$f_{\text{eff}} = \frac{R}{\mu_1 - \mu_2}$$

$$f_{\text{eff}} = \frac{R}{\mu_1 - \mu_2}$$



$$\frac{1}{f} = (\mu_1 - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\frac{1}{f} = (\mu_1 - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

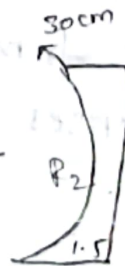
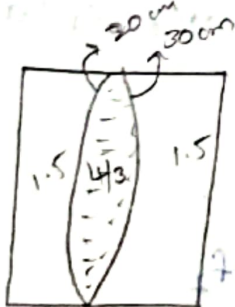
$$\frac{1}{f_1} = (\mu_1 - 1) \left(\frac{1}{\infty} + \frac{1}{R} \right)$$

$$\frac{1}{f_2} = (\mu_2 - 1) \left(\frac{1}{R_1} - 0 \right)$$

$$\frac{1}{f_1} = (\mu_1 - 1) \left(\frac{1}{R} \right) \rightarrow \text{①}$$

$$\frac{1}{f_2} = \frac{(\mu_2 - 1)}{R} \rightarrow \text{②}$$

> (Q) Two plano-concave lens each of refractive index 1.5 filled with liquid of refractive index $\frac{4}{3}$. Each of radius of curvature 20cm and 30cm arranged as show in figure.



$$\frac{1}{f_3} = \left(\frac{4}{3} - 1 \right) \left(\frac{1}{R_1} + \frac{1}{R_2} \right)$$

$$\frac{1}{f_3} =$$

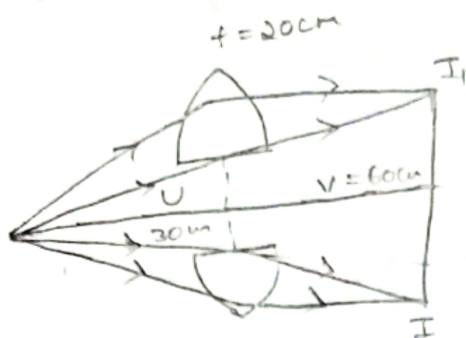
$$\frac{1}{f} = \frac{1}{2} \left(\frac{1}{20} \right)$$

$$f_1 = 40$$

$$f_2 = 60$$

$$f_3 = \frac{1}{\frac{1}{3} + \frac{1}{20} + \frac{1}{60}}$$

> Q1) A convex lens of focal length 20cm. It is divided into two parts and increase the separation 0.1cm. Find distance b/w the images.



30/04/2024 :- (Mon) :-

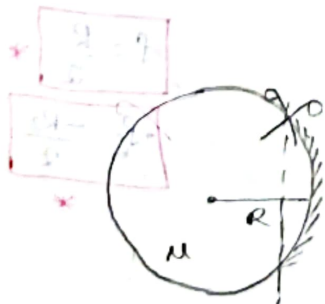
(IIT) (Adv)

* Silvering of Lens *

> A solid glass sphere of refractive index μ and radius R . A small portion removed from the one corner and coated with silver is called silvering.

Q of lens:

* When lens coated with silver it behaves like a mirror.



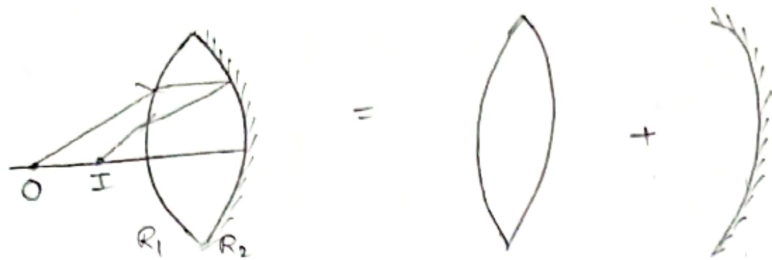
It act as a mirror

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f_{eff}}$$

* (CvV) *

⇒ Application-① :-

> A convex lens of refractive index μ and radius of curvatures R_1 and R_2 . The silvering on R_2 the effective focal length



$$P_{\text{eff}} = P_L + P_M + P_L$$

* $P_{\text{eff}} = 2P_L + P_M$ (for mirror)

$$P = -\frac{1}{f} \text{ (mirror)}$$

$$P = \frac{1}{f} \text{ (lens)}$$

$$-\frac{1}{f_{\text{eff}}} = 2\left(\frac{1}{f_L}\right) - \frac{1}{f_M}$$

For concave lens :-

$$-\frac{1}{f_{\text{eff}}} = \frac{2}{f_L} - \frac{1}{f_M}$$

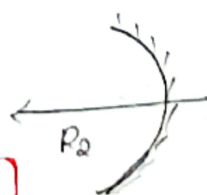
* $\frac{1}{f_{\text{eff}}} = \frac{1}{f_M} - \frac{2}{f_L}$ * **VVI**

$$\frac{1}{f_L} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\frac{1}{f_L} = (\mu - 1) \left(\frac{1}{R_1} + \frac{1}{R_2} \right)$$

For concave lens :-

$$\frac{1}{f_{\text{eff}}} = -\frac{2}{R_2} - \left[2(\mu - 1) \left(\frac{1}{R_1} + \frac{1}{R_2} \right) \right]$$



* $f = \frac{R}{2}$ *

* $f_M = -\frac{R_2}{2}$ *

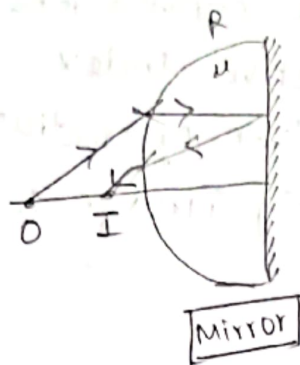
* $\frac{1}{f_{\text{eff}}} = - \left[\frac{2}{R_2} + 2(\mu - 1) \left(\frac{1}{R_1} + \frac{1}{R_2} \right) \right]$ *

* (VVI) *

(-ve) sign indicates concave mirror.

⇒ App-②:-

➤ A planoconvex lens coated with silver on plane surface. The radius of curvature R and refractive index μ . The effective focal length is :-

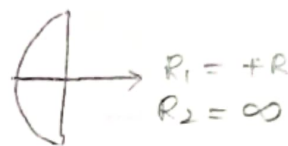


For lens:

$$P_{eff} = 2P_L + P_M$$

$$-\frac{1}{f_{eff}} = 2\left(\frac{1}{f_L}\right) - \frac{1}{f_M}$$

$$\boxed{\frac{1}{f_{eff}} = \frac{1}{f_M} - \frac{2}{f_L}} \quad \checkmark \text{ w.r.t.}$$

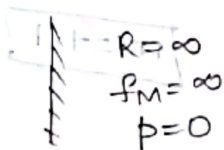


$$\frac{1}{f_L} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\frac{1}{f_L} = (\mu - 1) \left(\frac{1}{R} - \frac{1}{\infty} \right)$$

$$\boxed{\frac{1}{f_L} = (\mu - 1) \left(\frac{1}{R} \right)} \quad \text{--- ①}$$

For mirrors:



$$\frac{1}{f_{eff}} = \frac{1}{f_M} - \frac{2}{f_L}$$

$$\frac{1}{f_{eff}} = \frac{-2(\mu - 1)}{R} + \frac{1}{\infty}$$

$$\left(f_{eff} = \frac{-R}{2(\mu - 1)} \right) \Rightarrow \boxed{f_{eff} = \frac{-R}{2(\mu - 1)}} \quad \checkmark \text{ w.r.t.}$$

➤ (Q) A planoconvex lens of refractive index 1.5 and radius of curvature 10cm. Plane surface coated with silver. The effective focal length is ---

(A) WKT,

$$\boxed{f_{eff} = \frac{-R}{2(\mu - 1)}}$$

$$\Rightarrow f_{eff} = \frac{-10}{2\left(\frac{3}{2} - 1\right)}$$

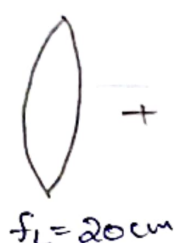
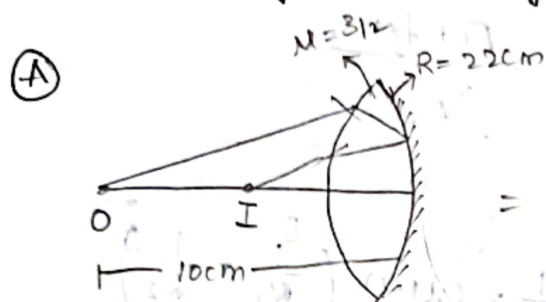
$$R = 10, \mu = 1.5$$

$$f_{\text{eff}} = \frac{-10}{2 \left(\frac{1}{2} \right)}$$

$$f_{\text{eff}} = -10 \text{ cm} \quad \checkmark$$

Adv (ii) previous:-

> (Q) A pin is placed 10 cm from the convex lens of focal length 20 cm with refractive index 1.5 and other surface coated with silver of radius of curvature 22 cm. Find position of image & nature of the image.



$$R = 22 \text{ cm}$$

$$f_M = -\frac{R}{2}$$

$$f_M = -\frac{22}{2} = -11 \text{ cm}$$

$$\frac{1}{f_{\text{eff}}} = \frac{1}{f_M} - \frac{2}{f_L}$$

$$\frac{1}{f_{\text{eff}}} = \frac{-1}{11} - \frac{2}{20}$$

$$\frac{1}{f_{\text{eff}}} = -\frac{1}{11} - \frac{1}{10}$$

$$= \frac{-10-11}{110}$$

$$f_{\text{eff}} = -\frac{110}{21} \text{ cm}$$

Mirror eqn

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f_{\text{eff}}}$$

$$\frac{1}{v} + \frac{1}{-10} = \frac{-21}{110}$$

$$\frac{1}{v} = \frac{1 \times 11}{10 \times 11} - \frac{21}{110}$$

$$\frac{1}{v} = \frac{11-21}{110}$$

$$\frac{1}{v} = \frac{-10}{110}$$

$$v = -11 \text{ cm} \quad \checkmark$$

① Real image

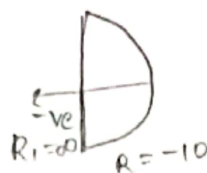
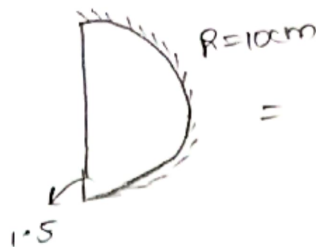
$$m = -\frac{v}{u}$$

$$m = -\left(\frac{+11}{+10} \right)$$

$$m = -1.1$$

> (Q) A plano convex lens of refractive index 1.5, $R = 10 \text{ cm}$ coated with silver on curved surface the effective focal length is:-

7



$$f_M = \frac{-R}{2} = \frac{-10}{2} = -5$$

$$\frac{1}{f_L} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\frac{1}{f_L} = \left(\frac{3}{2} - 1 \right) \left(\frac{1}{\infty} + \frac{1}{10} \right) = \frac{1}{2} \times \frac{1}{10} = \frac{1}{20}$$

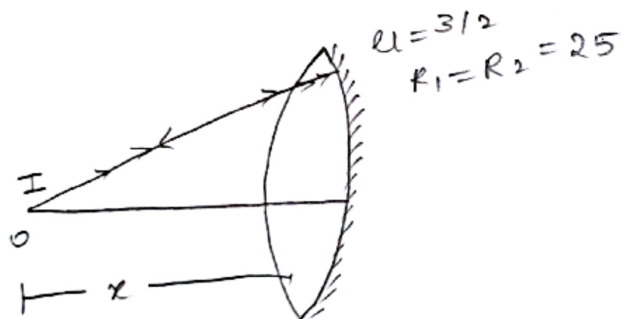
$$f_L = 20\text{cm}$$

$$\frac{1}{f_{\text{eff}}} = \frac{1}{f_M} - \frac{2}{f_L} \Rightarrow = -\frac{1}{5} - \frac{2}{20 \times 10} = \frac{-1 \times 2}{5 \times 2} - \frac{1}{10} = \frac{-3}{10}$$

$$f_{\text{eff}} = -10/3 \text{ cm}$$

> (Q) A Biconvex lens refractive index $\frac{3}{2}$ and radius of curvature 25cm for each side. One of the surface coated with silver. The object forms the image by itself. Find distance b/w object and mirror

$$x = 12.5\text{cm}$$



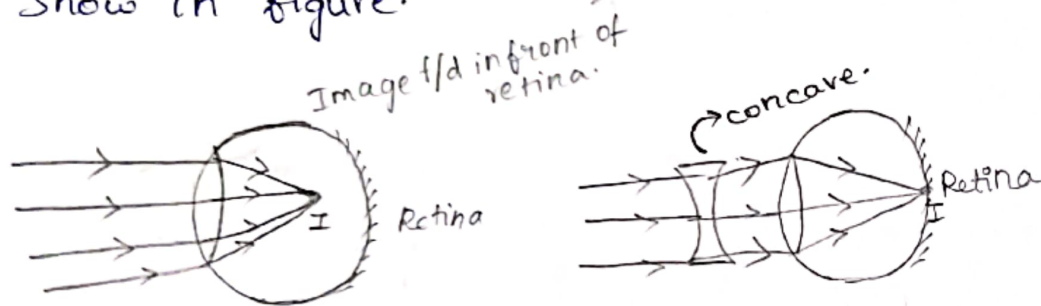
30/04/2024 (Mon):-

* Defects in Eye *

* Myopia (or) Short Sightedness :-

> A person who is suffering from myopia they unable to see for distance objects. Image is formed in front of the retina. Due to more power of the lens.
eye

> If we use concave lens with suitable focal length image is f/d on retina. As show in figure.



⑤ A person suffering from myopia. He can able to see upto 100cm from the eye but he unable to see far objects. Find power of the lens, nature of the lens.

$$U = -\infty$$

$$V = -100\text{cm}$$

$$f = ?$$

$$\frac{1}{V} - \frac{1}{U} = \frac{1}{f}$$

$$\frac{1}{-100} - \frac{1}{\infty} = \frac{1}{f} \Rightarrow \frac{1}{f} = \frac{-1}{100} \Rightarrow \boxed{f = -100\text{cm}}$$

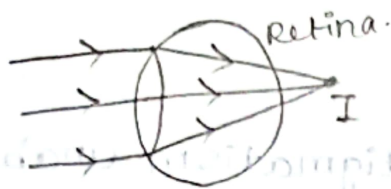
$$P = -\frac{1}{100\text{cm}} = -\frac{100}{100\text{m}} = \frac{-1}{\text{m}} = -1\text{D}$$

$$\boxed{P = -1\text{D}}$$



* Hypermetropia (or) long sightedness :-

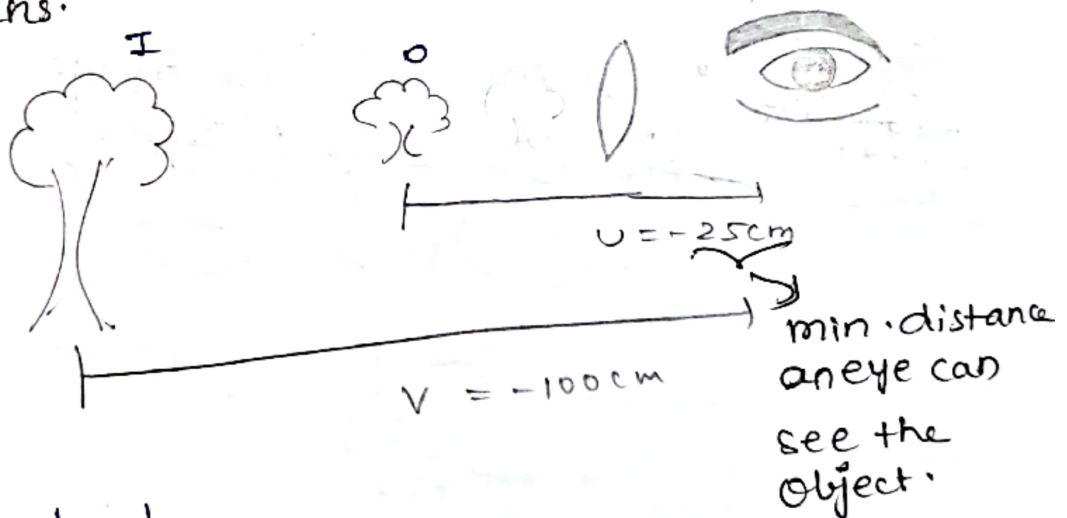
> A person is suffering from hypermetropia the image is formed beyond retina. If we use convex lens for suitable focal length then image is f/d on retina as show in figure.



Q)

A person suffering from hypermetropia. He unable to see upto 100cm from the eye but he can able to see far objects. Find focal length of the lens and nature of the lens.

(A)



$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{f} = \frac{-1}{100} + \frac{1 \times 4}{25 \times 4}$$

$$\frac{1}{f} = \frac{-1}{100} + \frac{4}{100} = \frac{3}{100}$$

$$P = \frac{100}{100\text{cm}} \times 3 = 3D$$

* Presbyopia :- (01/05/2024 (Wed)) :-

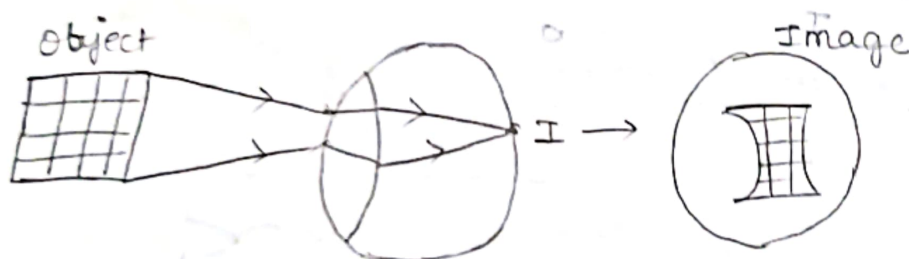
> A person who is suffering from presbyopia unable to see distant and near objects. It is due to weakness of the eye muscles.

> If we use Bifocal lens image is f/d on retina

* Astigmatism :-

> A person suffering from astigmatism unable to see horizontal and vertical lines due to uneven eye lens.

> To rectify astigmatism by using cylindrical lens with suitable focal length.



← * Optical Instruments * →

> Introduction :- Optical Instruments are two types :-

① Microscopes

② Telescopes

① Microscopes :-

- > Microscopes are used to study the small objects like bacteria and virus.
- > It has small focal length and small aperture.

$$\text{Focal length } (f) \propto \text{Aperture } (A)$$

- > Microscopes increase the linear magnification of the image.

- > Microscopes are classified into two types:-

(i) Simple microscope

(ii) Compound microscope.

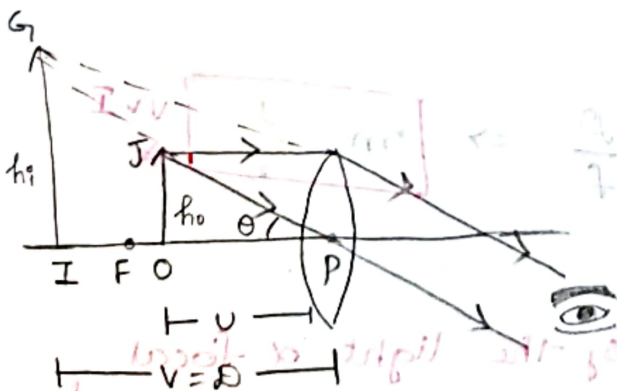
(i) Simple microscope :-

- > A simple microscope consists a single convex lens of focal length 'f'. Object arranged b/w F and P, image f/d same side of the object, but it is Virtual, erected and enlarged.

From Δ le's POJ and PIG:-

$$\frac{h_o}{u} = \frac{h_i}{v}$$

$$\frac{h_i}{h_o} = \frac{v}{u} *$$



$$\text{Magnification } (m) = \frac{v}{u} = \frac{h_i}{h_o}$$

$$* m = \frac{v}{u} * \text{VII.}$$

⇒ Case - (1) :-

Condition for maximum magnification:

$$u = -u \quad ; \quad v = -\infty$$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{f} = \frac{1}{-\infty} + \frac{1}{u} \quad (\text{Multiply with 'D' o.B.s})$$

$$\frac{D}{f} = \frac{D}{-\infty} + \frac{D}{u}$$

$$\frac{D}{u} = \frac{D}{f} + 1$$

$$m = 1 + \frac{D}{f} \quad \text{VVI} \\ \text{***}$$

⇒ Case - (2) :-

Condition for minimum magnification

$$u = -u \quad ; \quad v = -\infty$$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{-\infty} + \frac{1}{u} = \frac{1}{f} \quad (\text{Multiply with 'D' o.B.s})$$

$$0 + \frac{D}{u} = \frac{D}{f} \Rightarrow \frac{D}{u} = \frac{D}{f} \Rightarrow m = \frac{D}{f} \quad \text{VVI} \\ *$$

* Note: The wavelength of the light $\propto$ focal length.
If wavelength increases, Magnification decreases

$$\text{VVI} * \left[\frac{D}{u} = m \right] *$$

In simple microscope :-

Maximum magnification is $4\times$ without any error and defects.

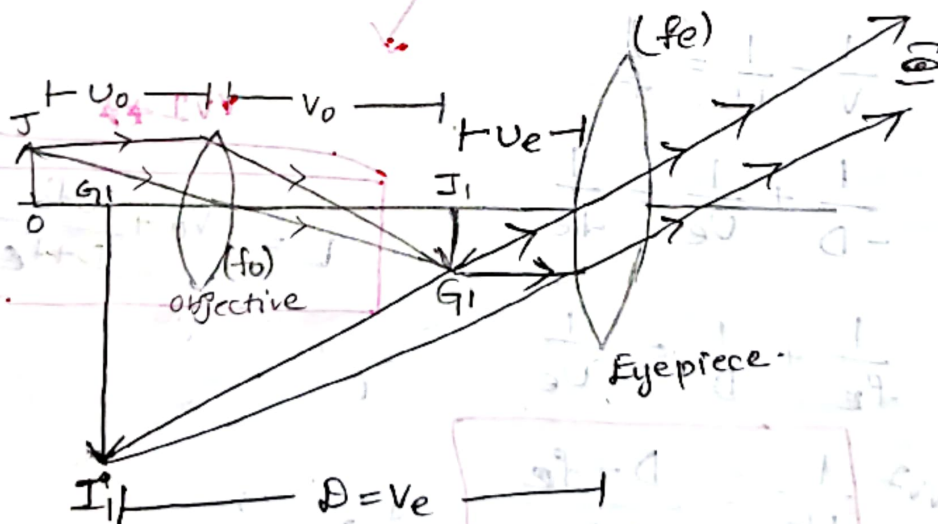
(ii) Compound microscope :-

> The compound microscope consists two convex lens which are arranged along the common axis inside the metallic tube with handle.

* A lens towards the object is called objective and a lens towards the eye is called eye piece.

> The object (OJ) arranged at a distance (U_o) it forms the image at a distance (V_o) from the objective.

> The image (I_1G_1) act as a object for eye piece. The final image (IG) f/d at a distance ' D ' as show in figure.



Net magnification $\Rightarrow m = m_o \times m_e$

VI

$\rightarrow$ max. magnification is some $20\times$.

⇒ Condition for maximum magnification:-

$$m = m_o \times m_e \quad \hookrightarrow \text{Case (I)}$$

$$m_o = \frac{+V_o}{-U_o}$$

$$m_o = -\left(\frac{V_o}{U_o}\right) \quad \text{*** VVI}$$

WKT,

$$m_e = \left(1 + \frac{D}{f_e}\right) \rightarrow \text{Inverted Simple microscope}$$

$$m = -\left(\frac{V_o}{U_o}\right) \left(1 + \frac{D}{f_e}\right) \quad \text{*** VVI}$$

$$D = 25 \text{ cm}$$

'-ve' sign indicates inverted image.

⇒ Length of compound microscope:-

$$L = V_o + U_e \quad \text{***}$$

$$U = -U_e$$

$$V = -D$$

$$f = f_e$$

$$\frac{1}{V} - \frac{1}{U} = \frac{1}{f}$$

$$\frac{1}{-D} + \frac{1}{U_e} = \frac{1}{f_e}$$

$$\frac{1}{f_e} + \frac{1}{D} = \frac{1}{U_e}$$

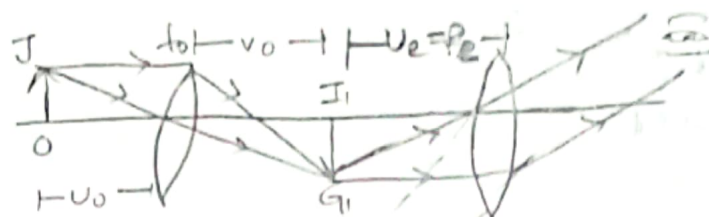
$$\text{VVI} \quad \frac{1}{U_e} = \frac{D + f_e}{D f_e}$$

$$\text{VVI ***} \quad L = V_o + \frac{D f_e}{D + f_e}$$

$$\text{*** IVV} \quad \text{VVI} \quad U_e = \frac{D f_e}{D + f_e} \quad \text{*** pacco.}$$

⇒ Case - (I) :- *पारदर्शी (CP)*

Condition for minimum magnification
(normal adjustment)



→ length of compound microscope $L = v_0 + f_e$ *VVI*

Magnification $(m) = m_o \times m_e$ *VVI*

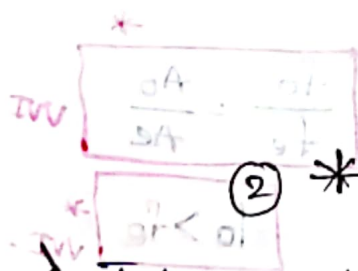
$$m_o = + \frac{v_0}{-u_0}$$

$$m_o = - \left(\frac{v_0}{u_0} \right)$$

$$m_e = \frac{D}{f_e}$$

Total magnification $(m) = m_o \times m_e$

$$m = - \left(\frac{v_0}{u_0} \right) \times \left(\frac{D}{f_e} \right)$$
 VVI



② * TELESCOPES *

➤ Telescope is an optical instrument which is used to study the distant objects like Sun, Star, moon etc..

➤ It is used to increase visual angle & angular magnification.

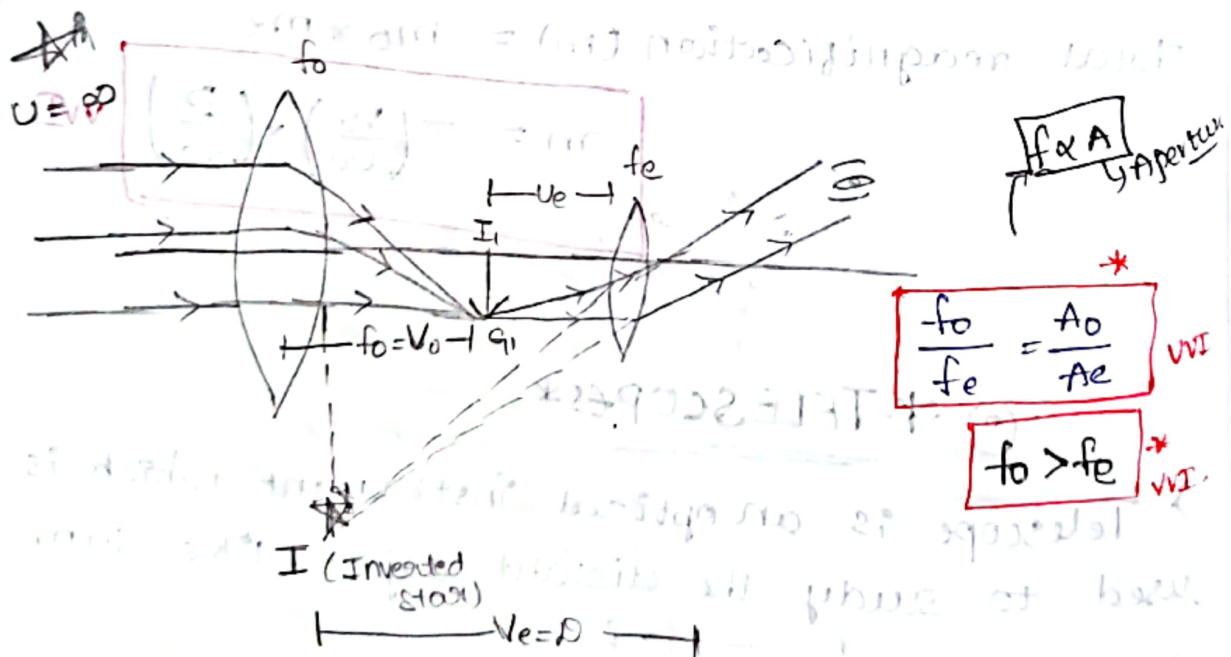
Types of telescopes :-

- ① Astronomical Telescope
- ② Galilean Telescope
- ③ Reflecting Telescope
- ④ Terrestrial Telescope.

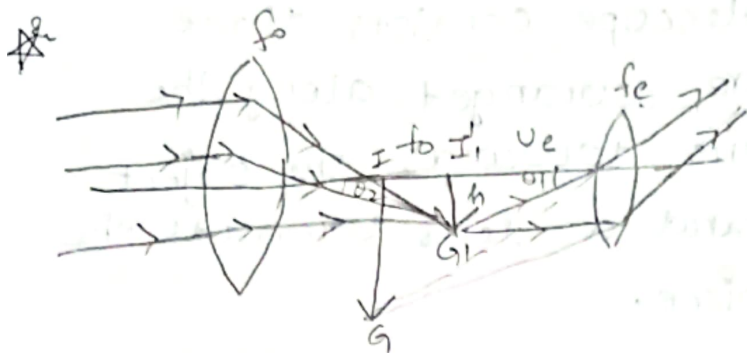
① Astronomical Telescope :-

> The Astronomical telescope consists two convex lens. A lens is towards the object is called Objective and focal length f_o . A lens towards the eye is called Eye piece.

★ When object at ∞ distance it form the image at principle focus f_o . The image ($I_1 G_1$) act as a object for eye piece. The final image ($I G$) formed at a distance ' D ' as shown in figure.



⇒ Case-① :-



Condition for maximum magnification

$$L = f_o + u_e$$

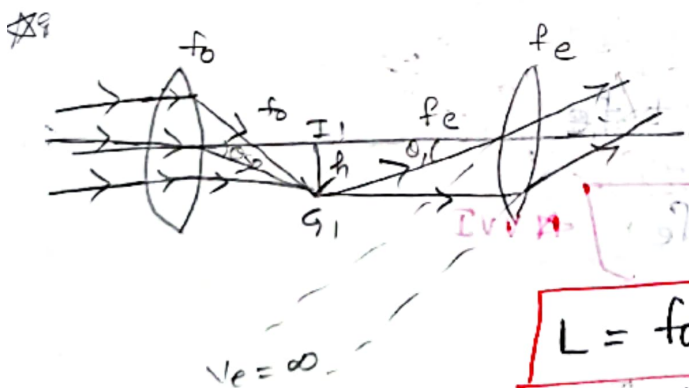
WKT :- $u_e = \frac{D f_e}{D + f_e}$

$$L = f_o + \frac{D f_e}{D + f_e} \quad \star \text{ VVI}$$

Magnification (m) = $\frac{\tan \theta_i}{\tan \theta_o} \Rightarrow m = \frac{+h}{-u_e} \times \frac{f_o}{+h}$

$$m = -\frac{f_o}{u_e} \quad \star \text{ VVI}$$

Case-② :-



Condition for minimum magnification

(Normal adjustment)

$$L = f_o + f_e \quad \star \text{ VVI}$$

$$m = \frac{\tan \theta_i}{\tan \theta_o}$$

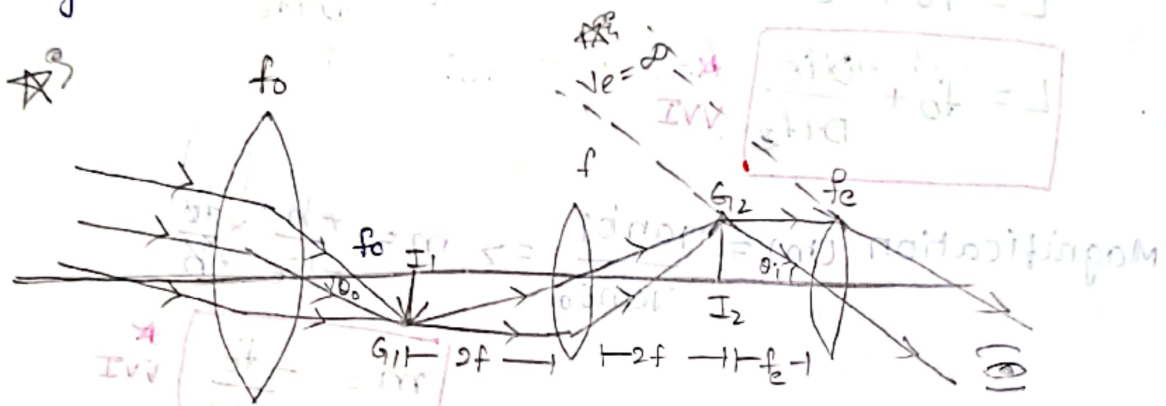
$$m = \frac{+h}{-f_e} \times \frac{f_o}{+h}$$

$$m = -\frac{f_o}{f_e} \quad \star \text{ VVI}$$

④ Terrestrial Telescope :-

> The terrestrial telescope consists three convex lens which are arranged along the principle axis. A lens towards the object is called Objective and a lens towards the eye is called Eye piece.

> A lens which is used for erect the image is called Erecting lens. Arranged as shown in figure.



Condition for (Normal adjust)
minimum
magnification

$$L = f_o + 2f + 2f + f_e$$

$$L = f_o + 4f + f_e$$

$$m = \frac{f_o}{f_e}$$

Condition for maximum magnification :-
(near point)

$$L = f_o + 4f + u_e$$

But $u_e = \frac{D f_e}{D + f_e}$

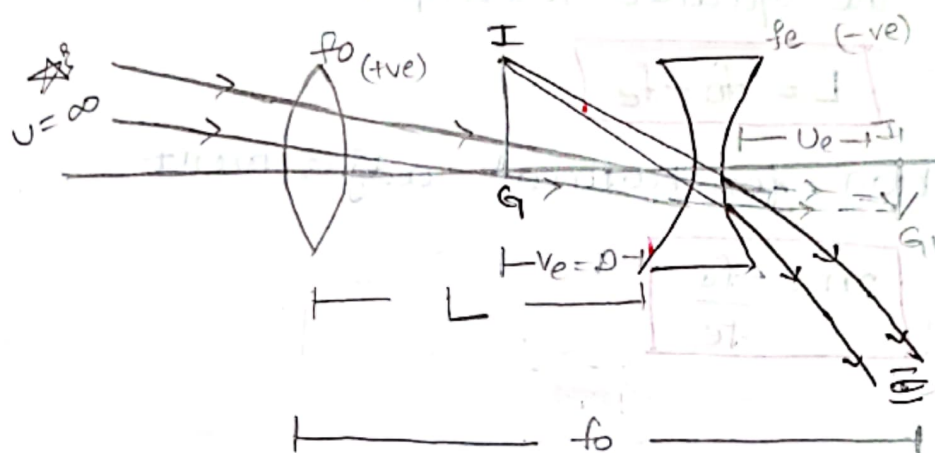
$$L = f_o + 4f + \frac{D f_e}{D + f_e}$$

02/05/2024 (Thu):-

② Gallileon Telescope :-

> The Gallileon telescope consists convex lens of focal length (f_o) and concave lens of focal length (f_e) arranged with common axis as shown in figure.

> Gallileon telescope has smaller visual angle & less field view



case-①:

The length of the Gallileon telescope at near point

$$L = f_o - U_e$$

But, $U_e = \frac{D f_e}{D + f_e}$

$$L = f_o - \frac{D f_e}{D + f_e}$$

> Magnification for near point

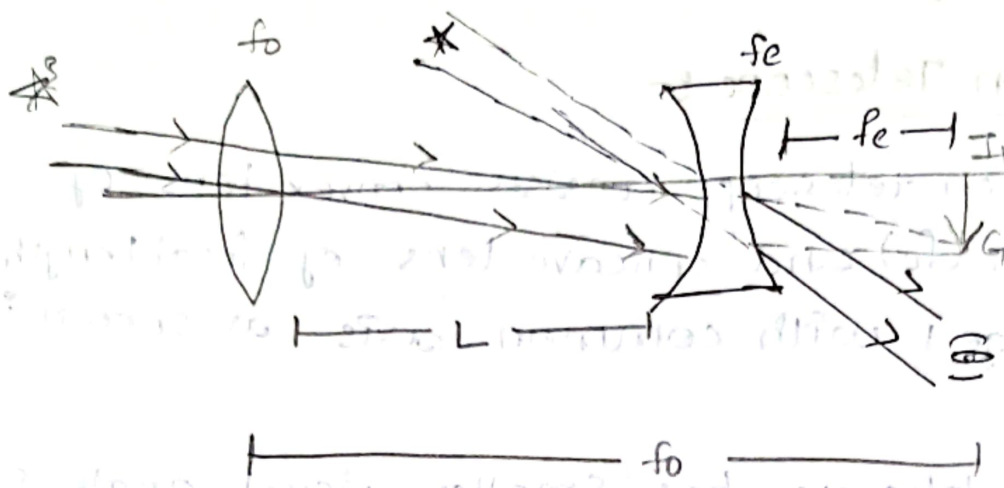
$$m = \frac{f_o}{f_e} \left(1 - \frac{f_e}{D} \right)$$

⇒ ***

Case-② :- (Always give (q) from this concept (para). only)

Condition for minimum magnification

(Normal adjustment)



Length of the Galileo Telescope for normal adjustment

$$L = f_o - f_e$$

Magnification for normal adjustment

$$m = \frac{f_o}{f_e}$$

(Corrected)

The length of the Galileo telescope at near point

$$L = f_o - f_e$$

$$1 = \frac{f_o}{f_e} - \frac{D}{f_e}$$

$$m = \frac{f_o}{f_e} \left(1 - \frac{D}{f_o} \right)$$

(Always give (D) from this correct)

magnification

02/05/2024 :-
(Thu)

L:1 → RAY OPTICS

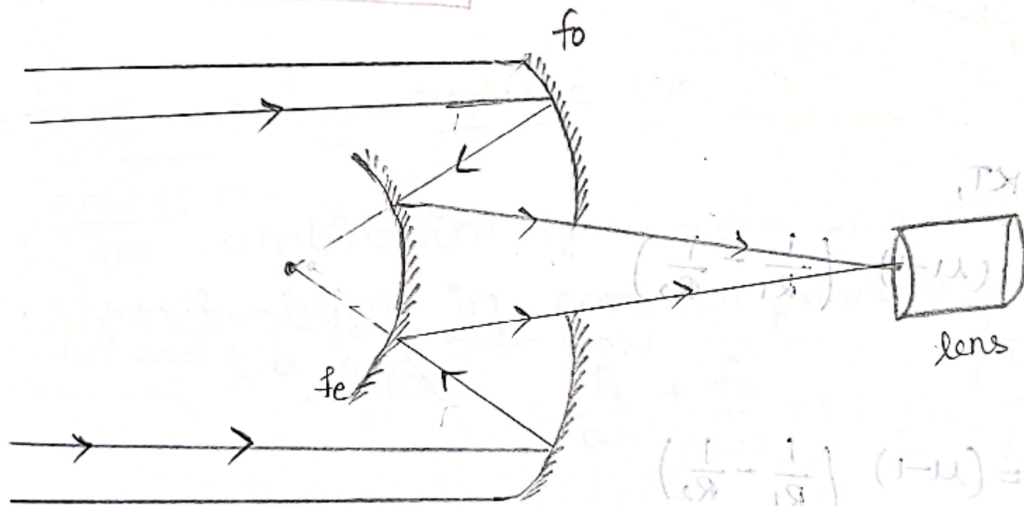
Sub Topic :- Optical Instruments :-

* Telescopes :-

③ Reflecting Telescope :-

> Introduction :- The reflecting telescope consists of two spherical mirrors which are arranged as shown in figure. Each of focal length ' f_o ' and ' f_e '.

> In reflecting telescope, image has more brightness and less defects. It produce real images.



Length of the reflecting telescope $(L) = f_o - f_e$

Magnification $(m) = \frac{f_o}{f_e}$

$$\left(\frac{1}{f} - \frac{1}{g}\right) u b = \frac{f b}{g}$$

$$\left(\frac{1}{(1-u)g} - \frac{1}{g}\right) u b = \frac{f b}{g}$$

* Chromatism:- III adv only

> When white colour light incident on the lens it can be split into different colours based on wavelength. The red colour has max. wavelength and max. focal length. But the violet colour has min. focal length & min. wavelength.

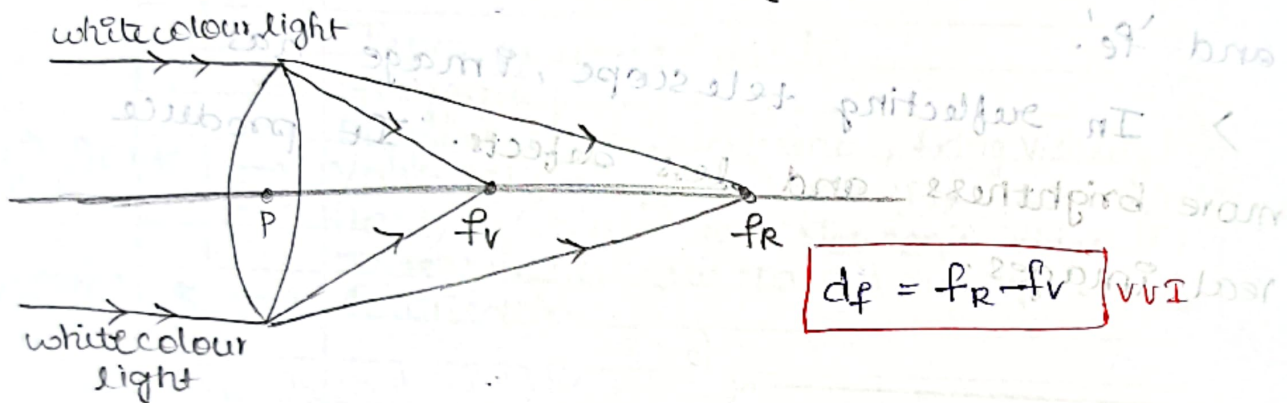
> It has max. refractive index.

(violet colour).

$$(\mu_v > \mu_r)$$

$$(f_r > f_v)$$

$$(\lambda_r > \lambda_v)$$



⇒ WKT,

$$\frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

Here take R_1, R_2 as fixed & μ, f are variables.

$$\Rightarrow f^{-1} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

By differentiation:-

$$(-1) f^{-2} \cdot df = (d\mu - 0) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$-\frac{df}{f^2} = d\mu \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

But $\left[\frac{1}{R_1} - \frac{1}{R_2} = \frac{1}{f(\mu - 1)} \right]$ (By lens maker's formula)

$$-\frac{df}{f^2} = du \left(\frac{1}{f(u-1)} \right)$$

$$-\frac{df}{f} = \frac{du}{u-1}$$

$$-\frac{df}{f} = \omega \left(\because \text{Dispersive power } (\omega) = \frac{du}{u-1} \right)$$

$$-df = \omega f$$

$$df = -\omega f$$

(OR)

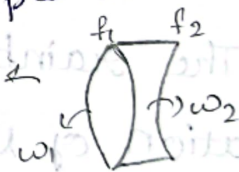
$$-\frac{df}{f} = \omega$$

$$\frac{f_R - f_V}{f_V} = -\omega$$

⇒ Condition to reduce the chromatic aberration: (mistake)

case (1) :-
> The combination of convex and concave lens arranged in common principle axis, as shown in figure.

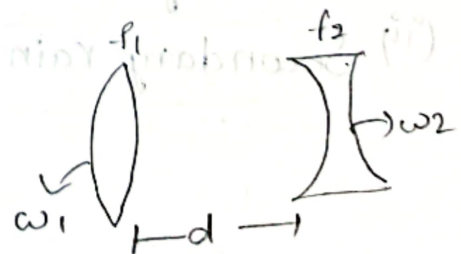
$$\frac{f_1}{\omega_1} + \frac{f_2}{\omega_2} = 0$$



⇒ case (2) :-

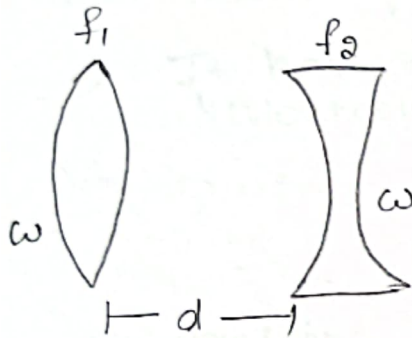
> A convex lens and concave lens each of focal length f_1 and f_2 , dispersive power ω_1 and ω_2 . Find minimum separation b/w the lens to reduce the chromatic aberration.

$$d = \frac{\omega_1 f_2 + \omega_2 f_1}{\omega_1 + \omega_2}$$



⇒ Case - (3) :-

A convex lens and concave lens each of focal length $-f_1$ and f_2 but same dispersive power. The separation b/w two lenses to minimize the chromatic aberration.



$$d = \frac{\omega_1 f_2 + \omega_2 f_1}{\omega_1 + \omega_2}$$

$$\omega_1 = \omega_2 = \omega$$

$$d = \frac{\omega f_2 + \omega f_1}{\omega + \omega}$$

$$d = \frac{\omega (f_2 + f_1)}{2\omega}$$

$$d = \frac{f_2 + f_1}{2}$$

* I.P.E Board syllabus :-

* RAINBOW * (2M) (or) (4M) ⇒ 6m

> The rainbow due to dispersion of light, deviation of light. The condition for rainbow is one side Sunshine and opposite side must be raining.

⇒ Rainbows are two types :-

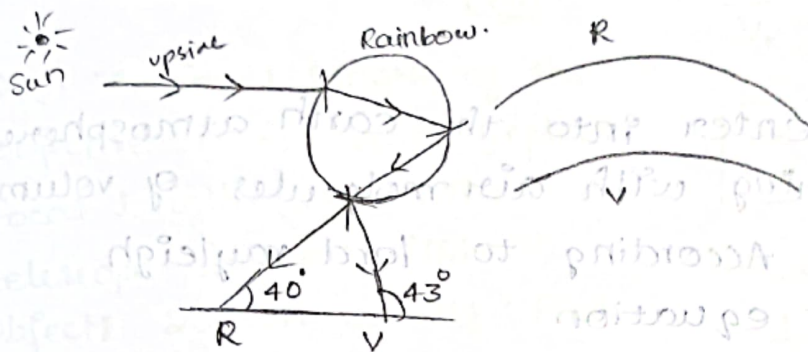
(i) Primary rainbow

(ii) Secondary rainbow

(i) Primary Rainbow :- (4m)

> The primary rainbow consists two refractions and one reflection.

> In primary rainbow, red colour f/d on outer region & violet colour f/d on inner region. As shown in figure.

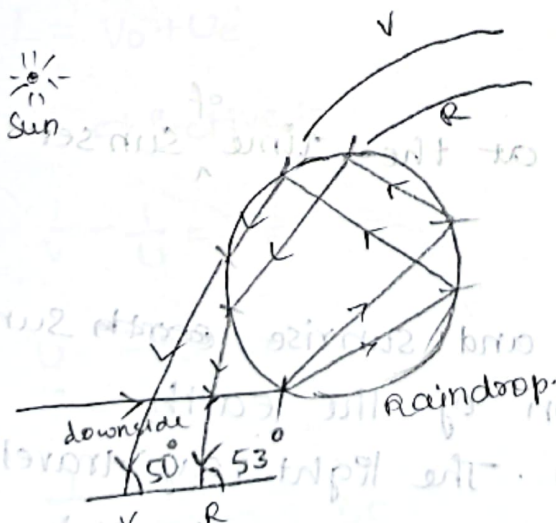


(ii) Secondary Rainbow :-

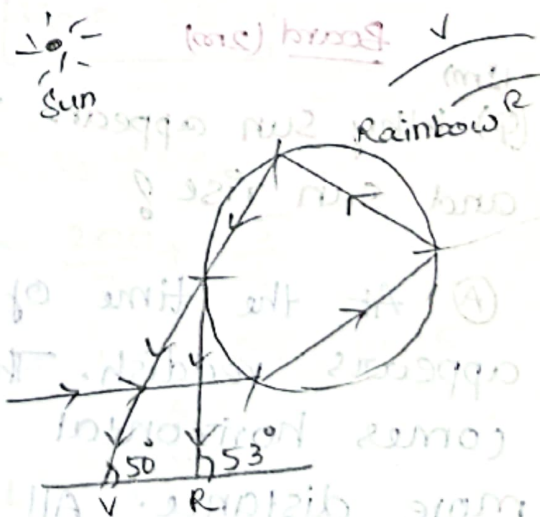
> Secondary rainbow consists two reflections & two refractions.

> In secondary rainbow image appears less brightness.

> In secondary rainbow violet appears on outer region and red colour appears on inner region. As shown in figure.



(OR)



* Lord Rayleigh Scattering of light :- (2m).

> Lord Rayleigh was the first Scientist to study the scattering of light from the air molecules.

> When sunlight travel through the earth atmosphere due to elastic collision light undergoes scattering (or) direction changes. This phenomenon is called Lord Rayleigh scattering of light.

For Advance (117):-

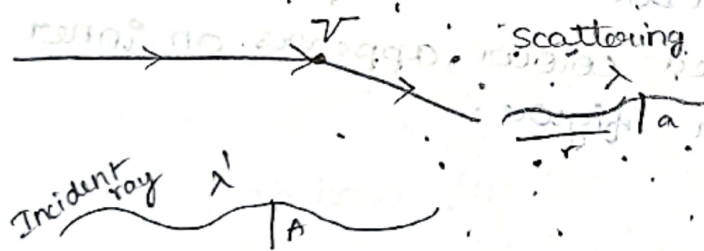
> When sunlight enter into the earth atmosphere it undergoes scattering with air molecules of volume 'V', amplitude 'a'. According to lord rayleigh scattering of light equation

Amplitude of scattering of light

$$a = \frac{AV}{r\lambda^2}$$

$$I \propto a^2$$

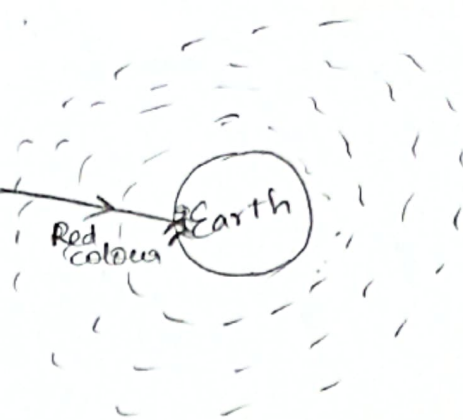
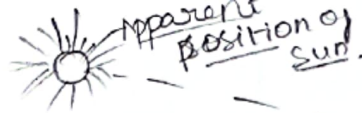
$$I \propto \frac{1}{\lambda^4}$$



Board (2m)

(2m) (Q) Why Sun appears reddish at the time ^{of} sunset and sun rise?

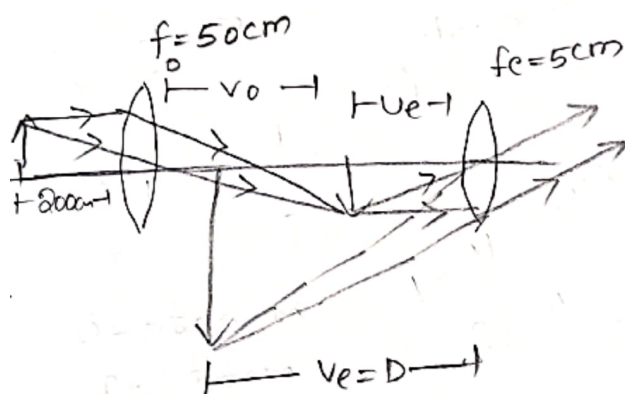
(A) At the time of sunset and sunrise ~~earth~~ sun appears reddish. The position of the earth comes horizontal direction. The light ray travel more distance. All colours are scattered only red colour travel more distance and strikes on the earth surface. So sun appears reddish as shown in figure.



* Questions * . 03/05/2024
(Fri)

Q) The focal length of the objective 50cm and eyepiece focal length 5cm. The telescope focused distant objects 200cm away. Find length of the telescope.

(A)



$$L = v_o + v_e$$

For objective :-

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$u = -200\text{cm}$$

$$f = +50\text{cm}$$

$$\frac{1}{v_e} - \frac{1}{-200} = \frac{1}{50}$$

$$\frac{1}{v_e} = \frac{1 \times 4}{50 \times 4} - \frac{1}{200}$$

$$\frac{1}{v_e} = \frac{3}{200}$$

$$v_e = \frac{200}{3}\text{cm}$$

For eyepiece

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$u = -v_e$$

$$v = -25\text{cm}$$

$$f_e = +5\text{cm}$$

$$\frac{1}{-25} + \frac{1}{v_e} = \frac{1}{5}$$

$$\frac{1}{v_e} = \frac{1 \times 5}{5 \times 5} + \frac{1}{25}$$

$$\frac{1}{v_e} = \frac{6}{25}$$

$$v_e = \frac{25}{6}\text{cm}$$

$$L = v_o + v_e$$

$$L = \frac{200}{3} + \frac{25}{6}$$

$$L = \frac{400 + 25}{6} = \frac{425}{6}$$

$$L = 70.8\text{cm}$$

$$L = 71\text{cm}$$